FINAL PROJECT TECHNICAL REPORT

Chariton Valley Biomass Project

Prepared for:
The United States Department of Energy
Contract Number: DE-FC36-96GO10148

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Acknowledgements

The Chariton Valley Biomass Project was managed by the Chariton Valley Resource Conservation and Development, Inc., based in Centerville, IA, and involved the efforts of project partners and team members from Portland, Oregon to Denmark. The Chariton Valley Biomass Project worked with numerous partners & team members over the years. Some of the early team members included; ABB Combustion Engineering, R.W. Beck, Black and Veach, Energy Research Corporation, E.L. Woolsey & Associates, Foster Wheeler Corporation and Sega, Inc. The accomplishments from this project are credited to the following Iowa entities that have participated in the project over the years: The Iowa Congressional Delegation; The County Supervisors in Appanoose, Lucas, Monroe and Wayne Counties; Soil District Commissioners in Appanoose, Lucas, Monroe, and Wayne Counties; Alliant Energy; Iowa State University; University of Iowa; USDA NRCS and FSA State Offices and the County offices in Appanoose, Wayne, Davis, Lucas, Monroe, Wapello, Marion, Mahaska, and Keokuk Counties; The Iowa Department of Natural Resources; Iowa Department of Agriculture and Land Stewardship; The Leopold Center; The Iowa Energy Center; The Iowa Farm Bureau Federation; Kelderman Manufacturing; Vermeer Manufacturing; John Deere Manufacturing; and Prairie Lands Bio-Products Inc. More information on the project's recent team members and the organizations cooperating in the project's research and development activities, see the information presented below.

IOWA-BASED PARTNERS

The Iowa-based partners and team members for the Chariton Valley Biomass Project included:

Chariton Valley RC&D, Inc.

Chariton Valley Resource Conservation and Development is a United States Department of Agriculture sponsored, non-profit organization serving Lucas, Wayne, Appanoose, and Monroe Counties in South Central, Iowa. The RC&D provides assistance to local communities, counties, and organizations to carry out local objectives related to economic development, community facilities, and natural resource conservation. Chariton Valley RC&D, Inc. is the prime contractor and grant-holder for the cost-shared research and demonstration phase of the Chariton Valley Biomass Project and manages all aspects of the project.

Alliant Energy

Alliant Energy Corporation (NYSE: LNT) is an energy holding company with regulated utility providers as well as non-regulated companies involved in delivering energy-related products and services. Located in Cedar Rapids, Iowa, Alliant Energy is a major energy producer in the state and has agreed to co-fire switchgrass at its Ottumwa Generating Station (OGS) during the demonstration phase of the project. If economic conditions are attractive after the cost-shared demonstration project is completed, Alliant Energy would consider entering intoa fuel supply contract with an entityto purchase switchgrass for up to 5% of the total fuel input at OGS on a continuing basis.

Prairie Lands Biomass, LLC

Prairie Lands Biomass, LLC is a switchgrass producer's organization that works with other partners to conduct project research, develop management and harvest techniques, and ensure a supply of switchgrass for energy generation.

Kelderman Manufacturing

Kelderman Manufacturing, Inc. was founded by Gary Kelderman in 1970 and is based in Oskaloosa, IA. They are known throughout the agricultural industry as one of the leading inventors of hay equipment, planter fold kits and rubber track systems for tractors and combines. Gary holds over 25 patents and is also a board member of Prairie Lands Biomass LLC. Kelderman Manufacturing has been instrumental in installing, optimizing, and operating the switchgrass processing equipment during the project's test burns. They are also developing and testing custom harvesting and baling machinery to improve efficiency and performance of those operations.

Iowa Department of Agriculture and Land Stewardship

The goals of the Iowa Department of Agriculture and Land Stewardship (IDALS) are:

1. Build a department of agriculture that can respond quickly and efficiently to changing global conditions in agriculture;
2. Increase Iowa's agricultural market share - both domestic and foreign, and assist in the removal of unnecessary barriers to agricultural trade;
3. Develop and encourage agricultural education and new avenues for Iowa producers to market their products, increasing the independent farmers impact on the market;
4. Add value in Iowa to agriculture by developing new products, and create a link for Iowa farmers with consumer-ready markets;
5. Preserve Iowa's precious soil, and improve water quality to ensure opportunities for future generations of Iowans; and
6. Protect consumers and producers by assuring the quality of Iowa agricultural products and animal health.

These goals are closely linked with those of the Chariton Valley Biomass Project, and IDALS has provided assistance to the project from its inception.

Iowa USDA – Natural Resource Conservation Service

The Natural Resources Conservation Service (NRCS) works to protect and improve natural resources across the state. NRCS staff provides technical assistance to the state's landowners, farmers, communities, groups and other agencies to help them protect and conserve the states natural resources including soil, water and wildlife habitat. Iowa NRCS employs many specialists—from soil scientists to wildlife biologists—to ensure the state's landowners have access to reliable and proven technical information. Technical assistance includes natural resource inventories and assessments, and assistance in developing and implementing conservation plans for private lands.

Soil & Water Conservation Districts

The Soil & Water Conservation Districts (SWCD) of Appanoose, Lucas, Monrow, and Wayne counties were very instrumental in the Chariton Valley Biomass Project. SWCD's are the local entity working closely with the USDA Natural Resource Conservation Service and the Iowa Department of Agriculture and Land Stewardship – Division of Soil Conservation to address the natural resource issues that are most critical in their districts.

Iowa Department of Natural Resources

The Iowa Department of Natural Resources (DNR) has a stated mission "To conserve and enhance natural resources in cooperation with individuals and organizations to improve the quality of life for Iowans and ensure a legacy for future generations." Many of the bureaus that compose the DNR's Conservation and Recreation Division where involved in the Chariton Valley Biomass Product including wildlife, fisheries, law enforcement, forestry and Parks & Preserves. The Environmental Services Division was also involved through several of its bureaus such as water quality, air quality compliance, Energy and Waste management, geological survey and Land Quality.

Iowa Energy Center

The Iowa Energy Center invests its resources to create a stable energy future for the state of Iowa by producing dividends that support Iowa communities, businesses and individuals. The Center's staff has conducted switchgrass gasification research and analysis in support of the Chariton Valley Biomass Project.

Iowa Farm Bureau Federation

The major farm sector advocacy organization, Farm Bureau is active in farm policy issues and in providing individual services to local farms. The Iowa Farm Bureau has been providing assistance with public information and serving as a liaison with producers for the Chariton Valley Biomass Project since the project's inception.

Iowa State University & Iowa State University Extension Service

Iowa State University is among the nation's leading universities in research and technology transfer accomplishments. Researchers and students from Iowa State have been involved and instrumental in nearly all areas of research and analysis for the Chariton Valley Biomass Project. They have led research efforts for the project in the following areas: fertility and yield trials, soil stabilization and soil quality, water quality impacts, carbon sequestration, avian and wildlife impacts, intercropping systems, yield optimization, cool season grass trials, disease and weed control, switchgrass production economics, switchgrass gasification research and analysis, and determining chemical characteristics for switchgrass and cool season grasses in the project region.

John Deere Works

Founded in 1837, John Deere is a worldwide corporation that today does business in more than 160 countries and employs approximately 46,000 people worldwide. It is one of the oldest industrial companies in the United States. Located in Ottumwa, Iowa, the worldwide forage research unit for John Deere, Inc. is providing support in the area of harvest and handling technology research and development. John Deere Ottumwa Works develops balers, mower conditioners, windrowers, mowers and rakes. John Deere supplied some of the equipment used by the Chariton Valley Biomass Project’s farmers for their harvest activities.

Leopold Center for Sustainable Agriculture

The Leopold Center is a research and education center with statewide programs to develop sustainable agricultural practices that are both profitable and conserve natural resources. The Center and its staff have worked with the Chariton Valley Biomass Project to estimate the costs of switchgrass production under various scenarios, assess farm-related environmental benefits of the project, assess policy issues, and support the outreach efforts of the project.

University of Iowa, Center for Global and Regional Environmental Research

The University of Iowa's Center for Global and Regional Environmental Research promotes interdisciplinary research efforts that focus on the multiple aspects of global and environmental change, including the regional effects of natural ecosystems, environments and resources as well as on human health, culture, and social sciences. The Center's staff has provided valuable analysis for the Chariton Valley Biomass Project regarding life cycle greenhouse gas emissions and valuation of societal benefits from the project.

Vermeer Manufacturing Company

Based in Pella, Iowa, Vermeer has been successfully manufacturing quality farm, construction, and industrial equipment for more than 55 years. Vermeer is a multi-million dollar company operating with roughly 1.5 million square feet of plant space while manufacturing and marketing roughly 100 different agricultural and industrial products worldwide. Vermeer manufactures a full line of haying equipment including large round balers, mowers, mower/conditioners, rakes, tedders, bale processors, silage wrappers, bale splitters, bale movers and hay handling equipment; plus a wide assortment of industrial equipment for tree, construction, environmental and underground utility service work. Vermeer has supplied some of the equipment used by the Chariton Valley Biomass Project's farmers for their harvest activities.

FEDERAL GOVERNMENT PARTNERS

Partners and cooperating organizations in the Federal government for the Chariton Valley Biomass Project included:

U.S. Department of Energy

The U.S. Department of Energy (DOE), through its Biomass Program, manages and provides federal cost-share funding for the research and demonstration phase of the Chariton Valley Biomass Project. The project was launched with the assistance of a competitively awarded grant through the Department of Energy's Biomass Power for

Rural Development solicitation. Private-sector partners have provided over 50% cost-share to match the federal funding.

U.S. Department of Agriculture

The U.S. Department of Agriculture, through the Natural Resources Conservation Service - NRCS - has provided vital management and technical assistance at the local level to the Chariton Valley Biomass Project since the project's inception. The USDA Farm Service Agency (FSA) was also a valuable partner through their support to the prject through oversight of conservation programs involved with the project.

National Renewable Energy Laboratory

The National Renewable Energy Laboratory (NREL) is the nation's primary laboratory for renewable energy and energy efficiency R&D. NREL develops renewable energy and energy efficiency technologies and practices, advances related science and engineering, and transfers knowledge and innovations to address the nation's energy and environmental goals. NREL has provided technical assistance to the Chariton Valley Biomass Project in the planning and execution of several of the project's test burns and equipment processing tests.

Oak Ridge National Laboratory

Oak Ridge National Laboratory (ORNL) is the Department of Energy's largest science and energy laboratory, and has been the DOE's lead laboratory for biomass feedstock research and development. ORNL has assisted the Chariton Valley Biomass Project in managing and reviewing all aspects of the project's feedstock development and farm-related research activities since the project's inception. The Bioenergy Feedstock Information Network, ORNL's gateway to biomass information, can be accessed at bioenergy.ornl.gov.

CONSULTANTS AND OTHER PARTNERS

Technical consultants and other team members for the Chariton Valley Biomass Project included:

ANTARES Group Inc.

ANTARES Group Inc. is a consulting firm headquartered in Landover, Maryland, and focused on introducing emerging energy technologies into the power, industry, and commercial building sectors. The firm specializes in renewable energy (biomass in particular) and energy-efficient technologies and offers a wide range of technical and analytical services to government and private-sector clients. ANTARES has been instrumental in the Chariton Valley Biomass Project's data collection and sampling efforts, test planning and analysis, economics analysis, fuel sales contract development, and provided general technical and management support to the project.

Bradford, Conrad, Crow Engineering Company

Based in Portland, Oregon, Bradford Conrad Crow Engineering (BCCE) is a multi-discipline engineering firm providing consulting, engineering, design, and project management services to facility owners, design professionals, and design-build contractors. BCCE is active in all facets of engineering and design for the wood products industry and other industries using materials-handling systems for bulk materials, including straw and other biomass products. With input from other members of the project's engineering team, BCCE has been the lead engineering firm for the design of the Chariton Valley Biomass Project's process systems and facilities.

Elsam Engineering (formerly TechWise, currently Danish Oil & Natural Gas or DONG Energy)

Elsam Engineering is an international engineering company specializing in energy and the environment. They are headquartered in western Denmark and are a subsidiary of the power utility Elsam who owns and operates a number of central and local power plants (including several straw-fired power plants) and wind power facilities. Elsam designed and built the first commercially operating straw/coal cofiring power plant in the world - Studstrup - and has been operating the system since 1995. Elsam Engineering is a valuable part of the Chariton Valley Biomass Project's engineering team, providing design and test planning consulting based on their extensive design and operations experience with straw-fired power plants in Europe.

T.R. Miles Technical Consultants

Based in Portland, Oregon, TR Miles assists in the development, design, installation, and testing of agricultural and industrial systems for materials handling, air quality, and biomass energy. The firm has been involved with Agricultural Fiber Association Inc., a non-profit association of Oregon straw merchants promoting straw utilization since 1975. During that period, the Oregon straw merchants have developed a 600,000 ton per year (and growing) market for their straw. TR Miles brings that experience and knowledge, and a wide range of design and operation experience for biomass materials handling and processing systems to the Chariton Valley Biomass Project's engineering team. TR Miles has been instrumental in the project's design, planning, and testing activities.

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1 Project Background and History

The Chariton Valley Biomass Project is a cooperative effort between the Chariton Valley Resource Conservation and Development, Inc., Alliant Energy (and its subsidiary, Interstate Power & Light), Prairie Lands Bio Products Inc., and the U.S. Department of Energy. Based in Southern Iowa, the Project's partners have sought to demonstrate the technical and commercial feasibility of producing power from locally-grown and harvested switchgrass and other native southern Iowa grasses. Switchgrass once grew abundantly in the soils of southern Iowa's rolling hills simply because the two were well-suited. This natural companionship, along with the excellent burn qualities of switchgrass, created interest in the potential of growing the plant on marginal land as an alternative energy crop and a renewable fuel supply for power generation at Alliant Energy's Ottumwa Generating Station (OGS) in Chillicothe, IA. The project is managed by the Chariton Valley Resource Conservation and Development, Inc., based in Centerville, IA. The project partners and team members are seeking to develop a new business opportunity for southern Iowa farmers, while creating local environmental benefits by improving air emissions, improving soil conditions on local farm lands, enhancing wildlife habitats, and reducing sediment and nutrient run-off from farm lands into local surface waters.

At the close of the demonstration phase, this project has measured and demonstrated the environmental impacts and benefits of a commercially operating switchgrass cofiring project in the area at all points in the process from the farm to the power plant. The project partners have been granted all necessary approvals and permits from regulatory and governmental agencies to enter into commercial operations at a switchgrass feed rate of 12.5 tons per hour at the power plant, representing up to about 2.5% of the boiler's total heat input at full load operations. If switchgrass use occurs at the power plant year-round, this approved average feed rate would translate to a new market in the area with a demand of about 100,000 tons of switchgrass per year. Based on permitting results to date, project partners anticipate that the facility could readily be permitted for an average feed rate of 25 tons per hour, or the equivalent of 5% of the power plant's heat input at full load operation. Approval has already been obtained from the Iowa Department of Transportation to use fly ash from OGS for cofiring switchgrass with coal at switchgrass feed rates up to 5% on a heat input basis for concrete admixture end-uses—this is a very important approval (the first of its kind in the U.S. for a biomass cofiring project), since fly ash sales generate a valuable co-product revenue stream from OGS. The facility that was constructed to process switchgrass to perform the project's final demonstration activity, the Long Term Test Burn, is already configured to house a second processing line which would double the existing processing capacity from 12.5 to 25 tons per hour.

1.1 Initial Drivers

In the mid-1990's, Chariton Valley RC&D Inc. in Centerville, Iowa targeted switchgrass as an energy crop that was well-suited to southern Iowa and could provide a variety of environmental and economic benefits for local farmers. At that time, the most attractive application for a large-scale switchgrass energy project was co-firing with coal in a utility power plant boiler. Alliant Energy agreed to team with Chariton Valley RC&D to investigate the feasibility of co-firing switchgrass at its Ottumwa Generating Station. At that time, Alliant Energy was interested in the potential for switchgrass cofiring to help the company meet possible future renewable power generation requirements and also as a means for reducing its greenhouse gas emissions from its existing and future coal plants. The original project feasibility study was conducted in 1996. Based on results of that study, project partners submitted a proposal to the Biomass Power for Rural Development solicitation from the U.S. Department of Energy's Biomass Power program. The project was competitively selected as one of the three awardees to receive further Federal funding. The Biomass Power for Rural Development program was a collaborative effort between the U.S. Department of Energy and the U.S. Department of Agriculture aimed at demonstrating and deploying integrated biomass power systems that are economically and environmentally viable and sustainable.

The stated expectations of the Biomass Power for Rural Development projects were:

- Demonstration of integrated biomass supply systems with power conversion technologies;
- Introduction of alternative energy crops as a means to offset federal agricultural subsidy payments;
- Economic revitalization of rural America and job creation;
- Reduction of greenhouse gas emissions;
- Improvements in biodiversity and ecological health; and
- Creation of a U.S. industry with significant potential for equipment and technology export.

With the present increased focus on national energy security and global environmental issues, the objectives stated above are even more important today than they were when the Biomass Power for Rural Development solicitation was issued. The Chariton Valley Biomass Project, through its wide range of research, demonstration, and development efforts, has shown that it is capable of meeting all of the expectations mentioned above. The next and final step for the project is to complete negotiations to move into commercial operations.

1.2 Ottumwa Generating Station

The Ottumwa Generating Station (OGS) is located just outside of Ottumwa, IA on the Des Moines River in the town of Chillicothe. The operating and site specifications for OGS are shown in Exhibit 1. The unit is a 726 MW dry-bottom, tangentially-fired, pulverized coal boiler with a twin furnace configuration and two fireballs. The unit was one of the first in the nation that was specifically designed to fire low sulfur Powder River Basin coal. Particulate emissions are controlled by a hot-side electrostatic precipitator. Fly ash is collected in a silo and is sold as an admixture for concrete--this generates a very valuable byproduct revenue stream from the plant. Bottom ash is sluiced to an ash settling pond East of the boiler house, and is reclaimed for application onto roads during icy conditions, or is used as base fill for road and construction projects. Alliant Energy's utility subsidiary, Interstate Power & Light (IPL), operates the plant and shares ownership with MidAmerican Energy Company (MidAmerican is the majority owner at 52 percent).

Exhibit 1 Operating Specification and Site Data for Ottumwa Generating Station

Max. Generator Output:	726 megawatts
Net Plant Output:	675 megawatts
Coal Type:	Low-sulfur Wyoming
Est. Annual Coal Consumption:	2 million tons
Max. Coal Consumption:	435 tons/hour
Max. Coal Unloading Rate:	3,500 tons/hour
Max. Coal Reclaiming Rate:	2,200 tons/hour
Max. Boiler Steam Production:	4,850,000 pounds/hour
Boiler Rated Capacity:	6,370 MMBtu/hour
Boiler Ash Production:	Bottom ash -- 5 tons/hour Fly ash -- 23 tons/hour Total -- 28 tons/hour
Precipitator Ash Removal:	99.4 percent
Main Building Height:	256.5 feet
Stack Height:	600 feet
Site Size:	800 acres
Commercial Operation Began:	May 22, 1981

Exhibits 2 and 3 show OGS and the locations of the switchgrass storage and processing facilities at the site. At the close of the demonstration project, there are three switchgrass storage facilities and one processing facility on-site. The initial switchgrass-related facility built on site was a 70 ft x 175 ft x 36 ft high metal building that served as storage and processing space for the project's first two test burns. This building is shown in Exhibit 3 to the East of the boiler house (the "Biosilo"), and was used for switchgrass storage once the new processing facility for the Long Term Test Burn was constructed. The two other storage facilities were built to the West of the property (across the fence) for the accumulation and storage of switchgrass on-site to enable the project's 3-month Long Term Test Burn.

Exhibit 2 Ottumwa Generating Station and On-site Switchgrass Storage Buildings

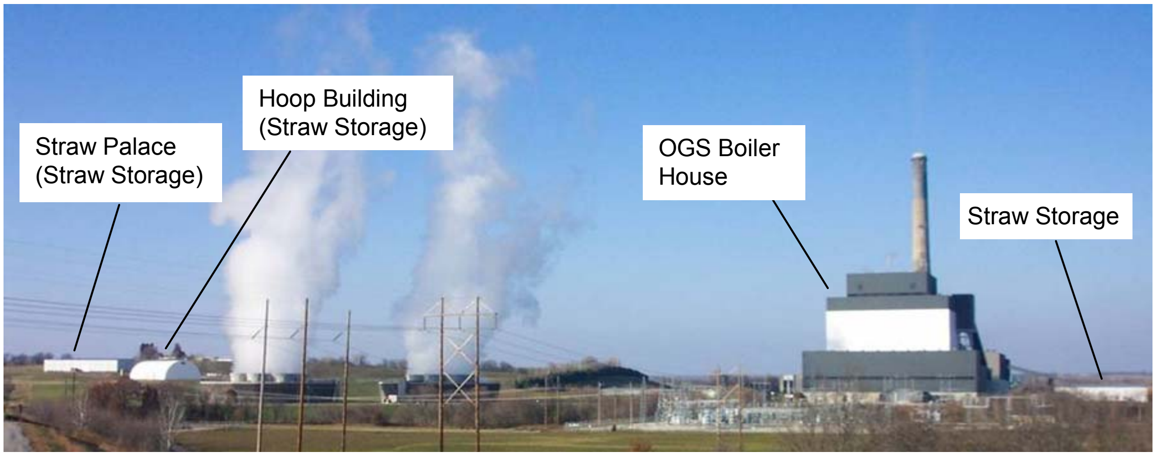
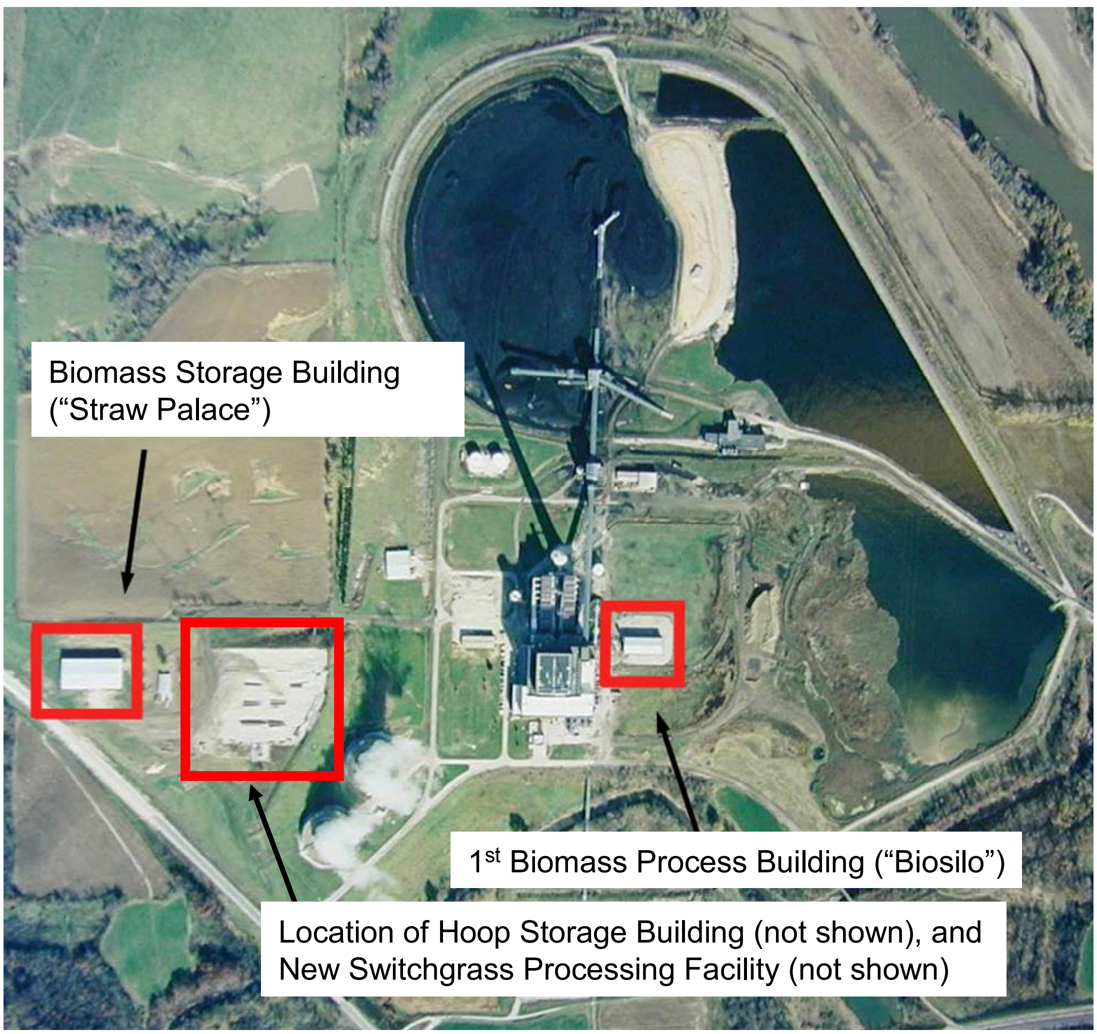


Exhibit 3 Aerial View of OGS and Locations of On-site Switchgrass Facilities

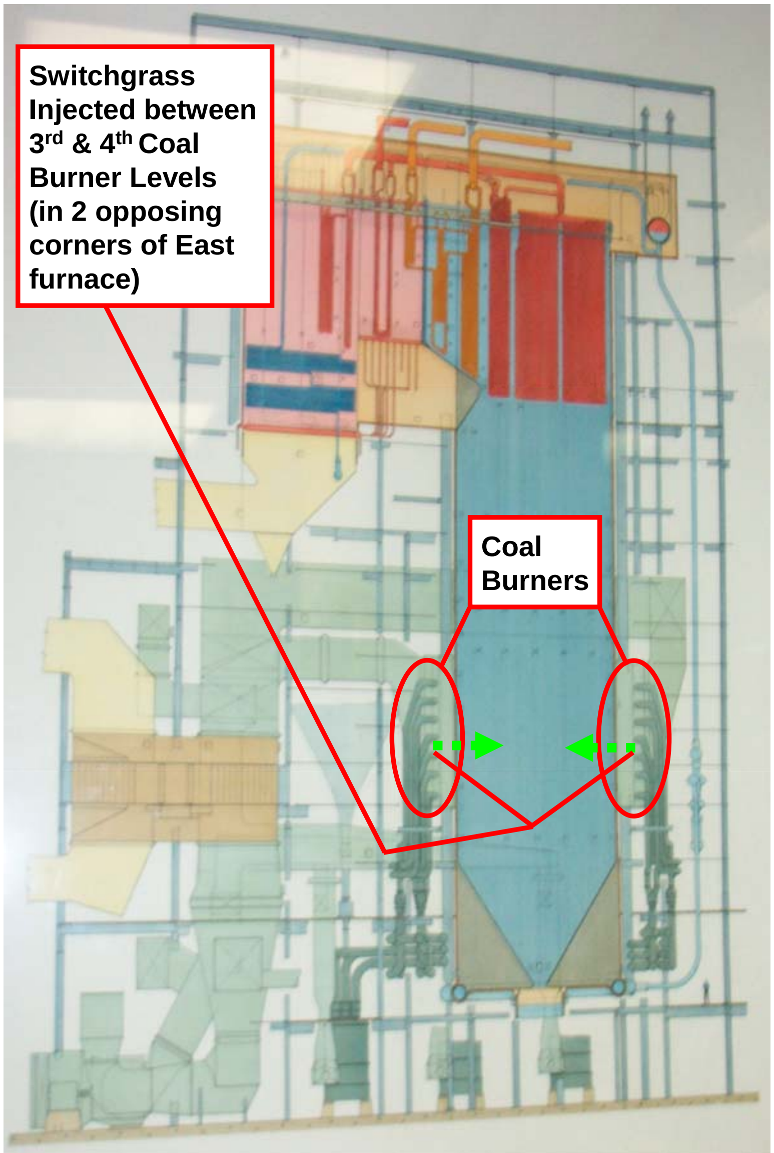


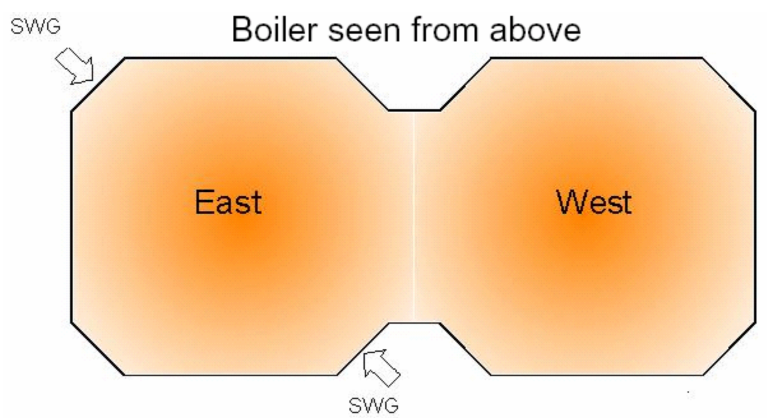
One of these facilities is a 125 ft x 200 ft x 30 ft high metal building (shown as the "Straw Palace" in Exhibits 2 and 3) with a storage capacity of about 4,000 tons of switchgrass. The other is a 76 ft x 200 ft x 35 ft high hoop building with a storage capacity of about 1,350 tons. The new processing facility, shown in Exhibit 4 (the "Grass Station"), is also located across the fence to the West of the main OGS property (as shown in the Exhibit 3 aerial photo). The new 70 ft x 233 ft x 40 ft high processing facility was built in this location to allow switchgrass-related delivery and employee traffic to be separated from the existing traffic and operations on the plant property, and because the location of the original processing and storage facility (the "Biosilo") was in an area reserved for the possible future construction of a second boiler house. As shown in the foreground of Exhibit 4, pneumatic pipes elevated about 17 ft above ground level at the power plant are used to transport ground switchgrass from the processing building to the OGS boiler.

Exhibit 4 New Switchgrass Processing Facility at Ottumwa Generating Station

Exhibit 5 shows a side view of the OGS boiler, which has two tangentially-fired furnaces without a separating wall between the furnaces. Each furnace has seven rows of coal burners in each of its four corners. The switchgrass was injected into the furnace through two burners located in opposite corners of the East furnace between the 3rd and 4th rows of coal burners. This location was chosen to help maximize switchgrass burnout in the furnace by providing several rows of coal flames above and below the switchgrass injection level. The lower coal flames provide heat and turbulence from below to help minimize the amount of unburned switchgrass that drops to the bottom of the furnace, and the upper coal flames help keep the switchgrass in the furnace long enough to be burned before exiting the top of the furnace.

Exhibit 5 Location of Switchgrass Injection into OGS Furnace





1.3 Locations of Switchgrass Fields and Storage Facility Characteristics

The switchgrass used during the project's test burns was primarily grown on 4,000 acres of CRP land within the area served by the Chariton Valley RC&D, which includes Lucas, Monroe, Appanoose, and Wayne counties. Through a pilot program with USDA, farmers were allowed to have their switchgrass harvested from their CRP land while still receiving their annual CRP rental payments for those acres, if the harvested switchgrass was used for this project. These four counties reside within the 70-mile radius from Alliant Energy's Ottumwa Generating Station, as shown in Exhibit 6. This 70-mile radius is targeted as the switchgrass supply region for a commercially operating Chariton Valley Biomass Project after the research and demonstration project has been completed. Exhibit 7 shows the locations of cooperator fields and switchgrass storage buildings within the four Chariton Valley RC&D counties relative to OGS. To minimize the hauling distance storage facilities were located within 10 miles of most cooperator fields.

A summary of the characteristics of the storage facilities used for this project is provided in Exhibit 8. The entire storage capacity of the facilities used was 24,495 tons. This storage capacity was needed since the Long Term Test Burn was targeted to use as much as 25,000 tons of switchgrass. With the exception of the hoop building located at OGS, the rest of the buildings were fully-enclosed metal buildings. Since only up to about 4,000 acres were available for annual harvests, and the yields per acre harvested typically ranged between 1.5 and 4.0 tons per acre, the storage inventory for the long term burn and the previous test burns had to be built up over multiple harvest seasons. Fully enclosed metal buildings were chosen in part because it was important to maintain the quality of the stored material for extended periods of time, in some cases for several years. It was important that the bales delivered to the processing facility during the Long Term Test Burn were of good quality and not weather damaged. With a few exceptions, the construction cost of most of the facilities shown in Exhibit 8 ranged from about $7.10 to about $10.50 per square foot. Of the 20 storage facilities built for the project, sixteen were built for less than $10 per square foot, fourteen were built for less than $9 per square foot, and eleven were built for less than $8 per square foot. The metal buildings with the largest footprints and the highest storage bays were the most cost-effective storage capacity employed, although they were more expensive than most buildings on a cost per square foot basis. The weighted average distance from the storage facilities to OGS for the switchgrass stored for the Long Term Test Burn was about 31 miles.

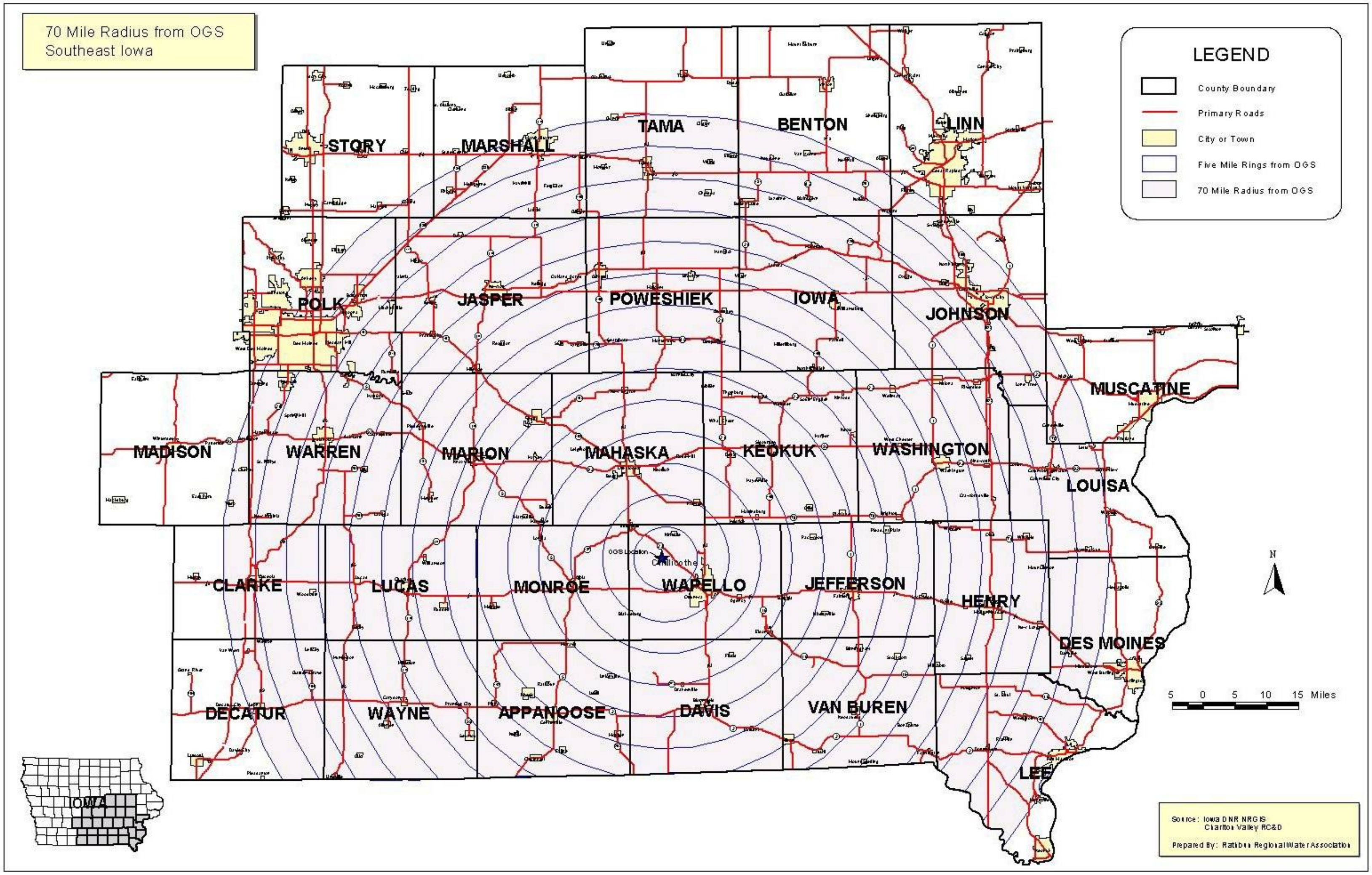


Exhibit 6 Targeted Switchgrass Supply Region (70-mile Radius from Ottumwa Generating Station)

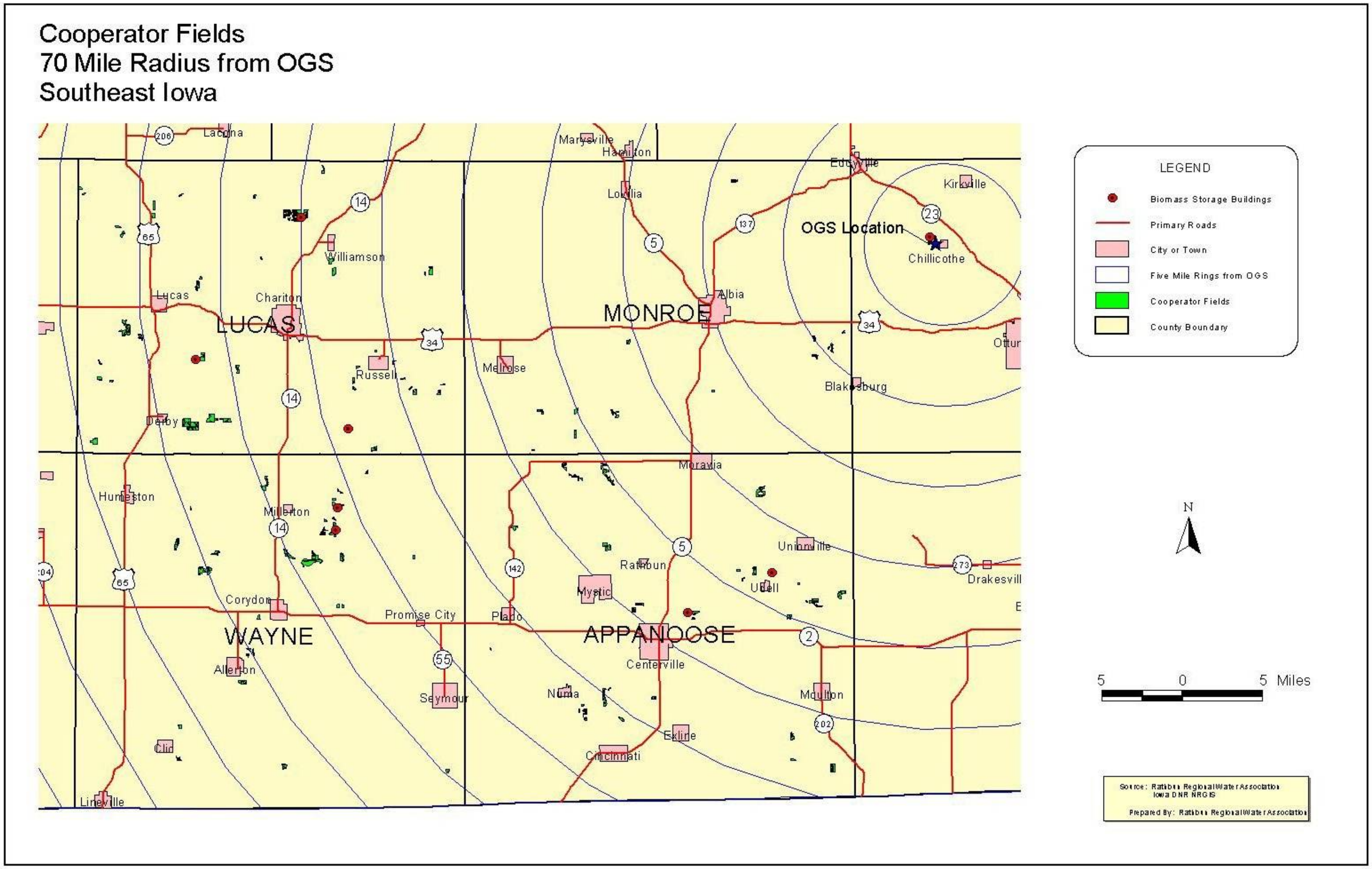


Exhibit 7 Locations of Cooperator Fields and Switchgrass Storage Buildings

Exhibit 8 Summary of Cost and Characteristics of Switchgrass Storage Facilities

Building Identifier (owner names removed for privacy)	Location	Year Built	Building Dimensions (ft)	Approx. Building Size (ft2)	Building Construction Cost ($)	Tons Stored for LTB	Distance from OGS (miles)
Straw Palace	Ottumwa, IA	1999-2000	125x200x30	25,000	$305,065	4,002	-
Storage Barn A	Corydon, IA	2000-2001	70x125x16	8,750	$66,000	321	61.0
Storage Barn B	Corydon, IA	2000-2001	70x125x16	8,750	$62,000	435	60.3
Storage Barn C	Chariton, IA; Lucas County	2000-2001	70x125x16	8,750	$65,000	461	45.4
Storage Barn D	Centerville, IA	2000-2001	70x125x16	8,750	$66,236	211	38.2
Storage Barn E	Corydon, IA; Wayne County	2000-2001	70x125x16	8,750	$62,000	450	62.2
Storage Barn F	English Twp; Lucas County, IA	2000-2001	70x125x16	8,750	$62,000	662	47.0
Storage Barn G	Centerville, IA	existing bldg.				998	39.7
Storage Barn H	Udell, IA	2000-2001	70x125x16	8,750	$116,000	361	38.7
Storage Barn I	Corydon, IA	existing bldg.				200	62.2
Storage Barn J	Corydon, IA; Wayne County	existing bldg.				306	62.2
Storage Barn K	Ottumwa, IA	existing bldg.				256	9.2
Bio Silo *	Chilicothe, IA; Wapello County	1999-2000	70x175x36	12,250	n.a.	1,208	-
Storage Barn L	Moravia, IA	existing bldg.			Temp.Storage	-	32.6
Storage Barn M	Millerton, IA; Wayne County	existing bldg.			Temp.Storage	-	56.2
Hoop Building	Power Plant Rd, Ottumwa, IA	2002-2003	76x200x35	15,200	$130,107	1,350	-
Storage Barn N	Cedar, IA	existing bldg.			n.a.	380	12.5
Storage Barn O	Lovilia, IA	2002-2003	125x200x30	25,000	$186,250	2,896	30.5
Storage Barn P	Corydon, IA	2002-2003	54x140x18.5	7,560	$79,175	913	58.7
Storage Barn Q	Corydon, IA	2002-2003	60x150x16	9,000	$79,970	688	61.9
Storage Barn R	Udell, IA	2002-2003	80x150x16	12,000	$75,090	764	42.2
Storage Barn S	Unionville, IA	2002-2003	80x150x16	12,000	$119,960	881	41.0
Storage Barn T	Corydon, IA	2003-2004	60x120x20	7,200	$46,500	594	63.5
Storage Barn U	Corydon, IA	2003-2004	70x136x20	9,520	$74,000	705	57.7
Storage Barn V	Moravia, IA	2004-2005	60x150x16	9,000	$89,970	598	27.5
Storage Barn W	Melrose, IA	2003-2004	80x150x20	12,000	$123,000	966	42.2
Storage Barn X	Albia, IA	2003-2004	60x120x20	7,200	$52,976	522	23.0
Storage Barn Y	Lovilia, IA	2003-2004	65x200x20	13,000	$108,290	900	29.4
Storage Barn Z	Centerville, IA	existing bldg.				2,364	40.4
Process Facility *	Power Plant Rd, Ottumwa, IA	2005	70x233x40	16,310	n.a.	104	-
Totals					**$1,664,524**	**24,495**	**30.6**

* NOTE: Only partial areas within the process facility and biosilo were available for switchgrass storage, since these facilities were designed primarily for processing operations.

Exhibit 9 summarizes the construction costs and average storage densities for several primary types of storage facilities that were built for the project: fully-enclosed metal buildings with 16-ft, 20-ft, and 30-ft high storage bays, and the single 76 ft x 200 ft x 35 ft high hoop building. Although averaged together the two 30-ft high metal buildings were the most expensive type of facility to construct on a cost per square foot basis, due to the significantly higher storage density within those buildings, they were the lowest cost to construct on a cost per ton stored basis, at less than half the cost per ton stored of the 16-ft high buildings. It should also be noted that the most recently built large 30-ft high metal building, the "Lodge Barn," was built for only $7.45 per square foot. The cost of that facility on a per ton stored basis was about $64.30. The storage density in that facility was about 232 pounds per square foot. The storage density in the "Straw Palace" (located adjacent to OGS), the other 30-ft high metal building, was 320 pounds per square foot. The 16-ft high buildings were built mostly in the early years of the project when the total storage requirements were lower. In general, the larger the building the more cost-effective the storage was. Of course, this must be balanced with the cost of getting the switchgrass from the local fields to the storage facility. Exhibits 10 and 11 show photos of each type of facility used for storage.

Exhibit 9 Summary of Storage Construction Costs by Facility Type

Storage Facility Description	Construction Cost/ft2	Lbs Stored/ft2	Construction Cost/Ton Stored
16-ft High Bays	$8.38	111	169
20-ft High Bays	$8.03	152	106
30-ft High Bays	$9.83	276	70
Hoop Building	$8.56	178	96

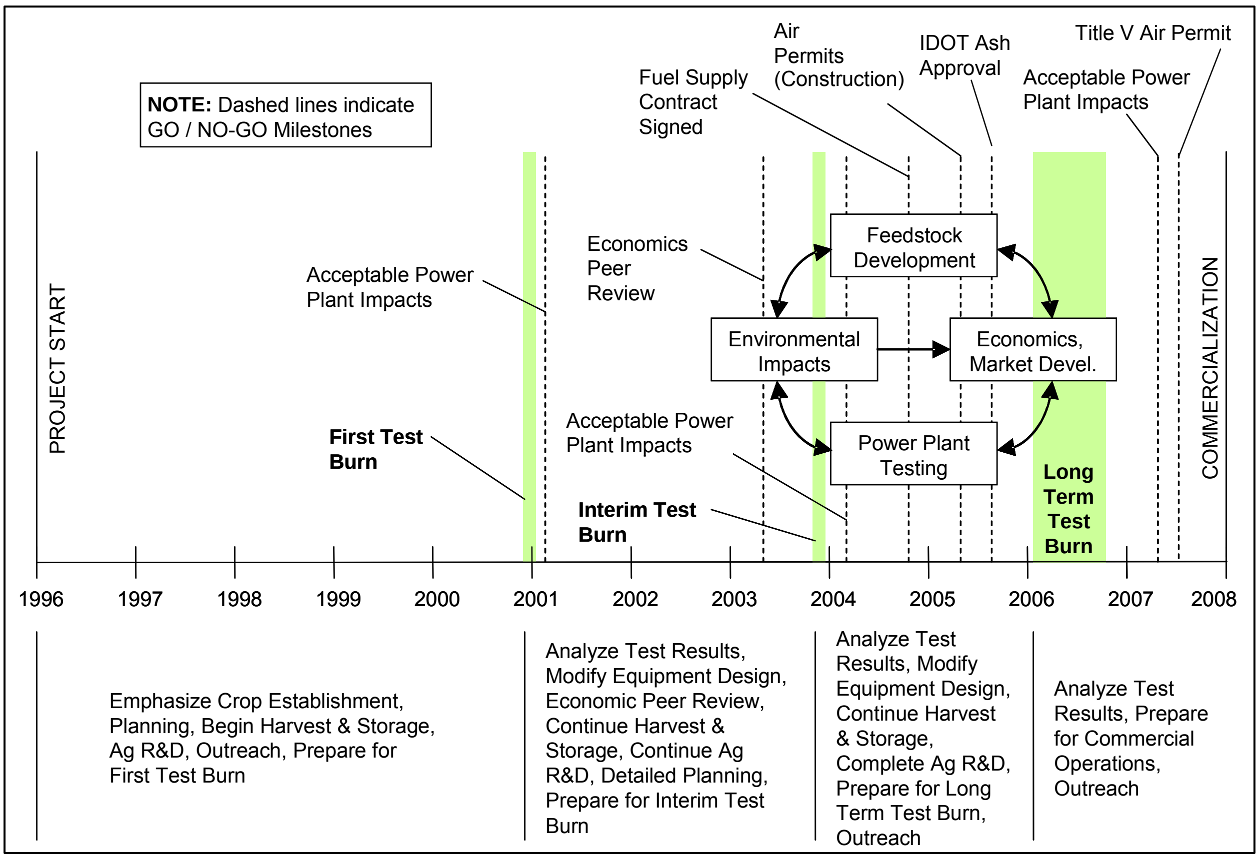
Exhibit 10 Typical Remote Storage Facility (70 ft x 125 ft x 16 ft high)

Exhibit 11 Hoop Building at OGS (76 ft x 200 ft x 35 ft high)

1.4 Project Timeline

A summary of key events and periods throughout the project's history is shown in Exhibit 12. The early years of the project focused primarily on farm-related studies, outreach to landowners for supplying switchgrass for the project's test burns, establishing switchgrass stands, building the initial group of storage facilities, performing the harvest operations to supply switchgrass for the first test burn at Ottumwa Generating Station, and planning and preparing for the first test burn. The first test burn was conducted during the Winter of 2000/2001 and involved temporary processing equipment, some of which was tractor driven, and a high degree of manual labor operations. The primary accomplishment of the first test burn was to demonstrate that at least for a short burn period, the impacts on the power plant's operations were acceptable--special monitoring emphasis was placed on the impacts on air emissions. A significant amount of learning was also accomplished regarding the processing requirements for grinding switchgrass for combustion in the plant's furnace.[1]

Exhibit 12 Summary of Project Timeline and Key Events



[1] For more information on the activities of the first test burn, see Section 2 of this report and: Amos, W., 2002, *Summary of Chariton Valley Switchgrass Co-fire Testing at the Ottumwa Generating Station in Chillicothe, Iowa: Milestone Completion Report*, NREL/TP-50-32424, National Renewable Energy Laboratory, Golden, CO.

The next period of the project's efforts involved analysis and application of the results and information collected during the first test burn, including designing processing equipment for a more permanent installation for the project's second test burn (the "Interim Test Burn"). A detailed economics peer review process was also conducted during this period to demonstrate and present the conditions under which the project could feasibly move forward into commercial operations following the close of the research and demonstration project. It should be noted that those conditions are either present today or are very close to being present, with a significant chance of occurring in the near-term if there is an increased demand/requirement for renewable power generation and/or carbon emissions reductions from electric utilities. Harvest and storage construction activities continued throughout this period to continue building the stored inventory of switchgrass to allow completion of the Interim and Long Term Test Burns. Based on the lessons learned from the first test burn, experience from operating Danish straw plants, and a series of field testing of prospective processing equipment, the processing system for the Interim Test Burn was designed and installed in the "Biosilo" building just East of the OGS boiler house. The Interim Test Burn was conducted during November and December of 2003.[2]

On the basis of information and test results obtained from the Interim Test Burn, the next period of the project's activities involved obtaining an air construction permit from the Iowa DNR to build a new, permanant processing facility to allow completion of a long duration (3-months) continuous test burn (the "Long Term Test Burn"). Approval was also obtained from the Iowa Department of Transportation to allow use of fly ash from switchgrass cofiring operations (up to 5% heat input from switchgrass), and a draft fuel supply contract for commercial operations (contingent of completion of a list of conditions during the Long Term Test Burn) was executed between IPL and Prairie Lands Biomass LLC, the farmer group seeking to be the switchgrass supply integrator for IPL during commercial operations. The completion of each of the activities mentioned above (air construction permit, IDOT approval, and draft fuel supply contract execution) enabled approval to be granted to design and build the new biomass processing facility shown in Exhibit 4.[3] The Long Term Test Burn and subsequent laboratory testing and engineering analysis demonstrated that there were no technical issues that should prevent the project from moving forward into commercial operations, and that the biomass processing facility could be operated reliably enough for commercial operation to be feasible if economic conditions are attractive enough and commercial contracting issues can be successfully negotiated. On the basis of emissions results measured and reported during the Interim and Long Term Test Burns, Chariton Valley RC&D, Inc. obtained a Title V air permit allowing commercial operation of the biomass processing facility at OGS in 2007. IPL's Title V operating permit for OGS was also modified to allow continued switchgrass cofiring. There are no remaining

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[2] For more information on the activities and Results of the Interim Test Burn, see Section 2 of this report and: Antares Group Inc., 2004, *Chariton Valley Biomass Project Interim Test Burn: Emissions Test Report (Test Burn of Switchgrass with Coal at Ottumwa Generating Station, Unit #1, Chillicothe, IA)*, Landover, MD.

[3] Sections 3 and 4 of this report contain more information on the biomass processing facility at OGS.

technical issues or demonstration-related requirements that need to be resolved prior to moving to commercial operation of the project.

1.5 Proposed Future Commercial Operation

From the outset of the Chariton Valley Biomass Project, project partners have sought to demonstrate the technical feasibility of cofiring locally grown switchgrass with coal to continuously generate up to 35 MW of biomass-derived electric power at the Ottumwa Generating Station (OGS), and to obtain all required approvals to do so on a commercial basis. To accomplish this during commercial operations, the project would require up to 200,000 tons of switchgrass annually from up to 50,000 acres, and would involve as many as 500 farmers. The switchgrass would be grown within 70 miles of OGS (Exhibit 6). One of the most environmentally important areas of switchgrass production would be in the Chariton River watershed. This watershed encompasses about 740,000 acres in southern Iowa. Common crops in southern Iowa are corn, soybeans, a variety of cool season forages and pasture species, and woodlots. The main limitations to crop production in southern Iowa have been steep, erosive landscapes, clayey soils that alternate between being too wet and too dry, and acidic subsoils. As a result, a large proportion of the land is enrolled in the Conservation Reserve Program, with corresponding areas being planted to switchgrass. These types of lands could provide much of the switchgrass used as fuel at OGS.

Switchgrass production (farming) and delivery are major steps required to supply up to 200,000 tons to OGS annually. A collection of storage buildings remote from OGS will be required for the switchgrass not transported directly to OGS during harvest season. Production steps include establishing, fertilizing, harvesting, and baling the crop. Delivery steps will usually involve moving the switchgrass from the field to off-site storage facilities, and eventually transporting the switchgrass to OGS for consumption. The farmers will use trucks with 53-ft. extended flatbed trailers to supply large square (3' x 4' x 8') bales of switchgrass to OGS. Each trailer will be loaded with bales stacked three high, two wide, and seven deep for a total of 42 bales per truck and a payload weight of about 42,000 lbs (average 1,000 lbs per bale), or 21 tons. During commercial operations, the switchgrass processing facility at OGS will require deliveries from about 200 flatbed trailers per week, or about 40 per day (840 tons per day) for a five-day delivery schedule. To process 200,000 tons per year of switchgrass, the processing facility would have to operate at an average rate of 25 tons per hour for 8,000 annual hours. At that rate, the switchgrass would provide about 5% of the heat input to the OGS boiler at full-load conditions. Exhibit 13 shows the process schematic for the new switchgrass processing facility located on the hill just west of the existing boiler plant facility (approximately 1,000 feet away). A second processing line would have to be added in the existing processing facility to enable operations up to 25 tons per hour. Engineering drawings of the site plans for the existing and proposed future construction are included in Appendix A. As indicated in the drawings, an automated bale storage and reclaim system using two overhead crane bays has been designed for possible future construction in case economic conditions allow it. These types of systems are used at several straw-fired energy plants in Europe.

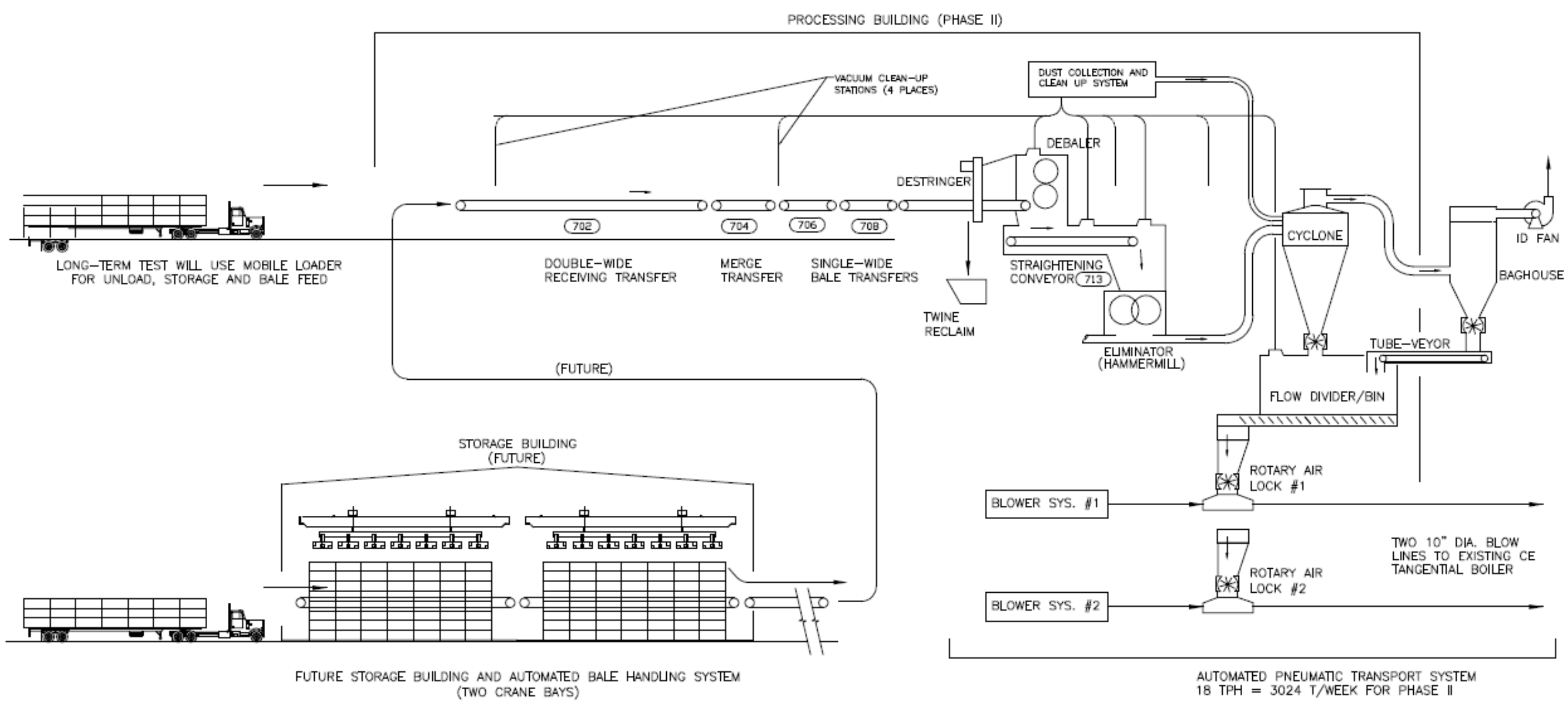


Exhibit 13 Process Schematic for Existing Biomass Processing Facility and Proposed Future Automated On-site Bale Storage and Reclaim Facility

2 Test Burn History and Summary Results

Three switchgrass and coal cofire test burns were completed during this project, each with increasing length and depth of activities, data and sample collection, and laboratory analysis. Exhibit 14 summarizes the amount of switchgrass processed and burned at OGS, on a monthly basis, during each test burn. In total, over 17,700 tons of switchgrass (over 37,300 bales) were burned during the three tests. This represented about 2% of the total heat input at Ottumwa Generating Station (OGS) during the co-fire periods. The average as-received heating values of the switchgrass are also shown, based on very detailed bale moisture content measurements throughout each test burn. On average, switchgrass processed and delivered to OGS had a higher heating value of 6,954 Btu/lb (about 13% moisture content). The total heat input from switchgrass throughout the three test burns was over 246,400 MMBtu. This is approximately the amount of energy theoretically required to boil 27 million gallons of water from room temperature or roughly 40 Olympic regulation swimming pools

Exhibit 14 Summary of Switchgrass Test Burn Tonnage and Heat Input Totals

Month	Switchgrass Burned (Tons)	Ave Heat Value, As-rec'd (Btu/lb)	Total Heat Input from Switchgrass (MMBtu)	% of Total Heat Input *
First Test Burn (Nov 30, 2000 to Jan 25, 2001)				
Nov-00	2.1	7,087	30	n.a.
Dec-00	307.4		4,357	
Jan-01	959.9		13,605	
Test Burn	1,267.3	7,087	17,963	
Interim Test Burn (Nov 21, 2003 to Dec 12, 2003)				
Nov-03	180.3	7,041	2,539	1.9%
Dec-03	601.0	6,897	8,290	
Test Burn	781.3	6,930	10,829	
Long Term Test Burn (Feb. 17 to May 12, 2006)				
Feb-06	1,098.0	7,049	15,480	2.0%
Mar-06	5,298.6	6,874	72,845	
Apr-06	6,321.7	6,962	88,017	
May-06	2,952.5	6,993	41,296	
Test Burn	15,670.8	6,944	217,638	
Project Totals	17,719.4	6,954	246,429	2.0%

* NOTE: Percent of total heat input number represents the percent of total heat input provided by switchgrass only during the periods when switchgrass was burned, and is not the % of heat input from switchgrass for the entire month including coal-only operation periods.

The first test burn was primarily aimed at demonstrating that switchgrass could be fired in the OGS boiler without causing short-term detrimental impacts to plant operations and air emissions. The second cofire test, the "Interim Test Burn," was aimed primarily at: 1) collecting information in support of obtaining air permits for construction of a permanent processing facility; 2) obtaining approval for IPL to continue to sell fly ash as a concrete admixture from OGS, even when burning switchgrass; and 3) to test the biomass processing system in advance of design and installation of the permanent processing facility. The primary objective of the third test burn, the "Long Term Test," was to collect information that could be used to assess the long-term impacts of burning switchgrass in the OGS boiler. The long term impact issues of most importance were primarily whether burning switchgrass would create slagging, fouling, or corrosion-related problems in the furnace or downstream equipment. The capabilities of the biomass processing system and its operators to provide a quality and reliable fuel supply on a continuous basis were also a key evaluation factor during the long term test. Also among the evaluation factors was the service provided by the biomass team to the plant staff and other staff within Alliant Energy throughout the test burn, including responsiveness to maintenance and technical issues, and ease and quality of communications throughout the test on technical performance and business matters (contract performance issues, invoicing, environmental reporting, technical reporting, public relations, etc.). The sections below summarize the activities and accomplishments of each of the three test burns.

2.1 First Test Burn

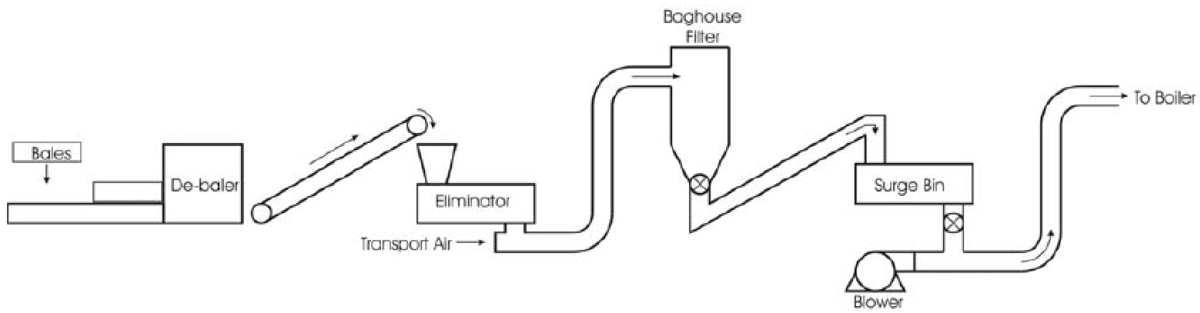
The first cofire test, conducted over the period from November 30, 2000 through January 25, 2001, resulted in the burning of 1,267 tons of switchgrass at feed rates as high as 16.5 tons per hour, or about 3% of total heat input at OGS.[4] This cofire test involved the use of temporary or test switchgrass feed equipment, some of which was rented because this test was viewed as a "proof-of-concept" exercise which was necessary before a significant investment was made in permanent equipment. For example, the debaling machine that performed the initial processing step on the bales was driven by a farm tractor, and the twine on the bales was cut manually using an axe. As a result of these and other similar equipment-related factors, the switchgrass feed process did not behave in a steady, consistent manner. The switchgrass feed rate varied between a few tons per hour up to 16.5 tons per hour. As a result, the boiler was rarely able to achieve steady-state operation. These conditions led to the collection of emissions data that would not be representative of continuous cofiring operations. In addition, because of the high level of manual effort required to simply sustain switchgrass feed to the boiler, it was not possible to accomplish thorough data collection on air emissions and other performance parameters. In particular, it was not possible to look back at the data set and correlate the continuous emissions monitoring (CEM) data with the cofiring rate (biomass input rate) for any particular time period. This cofire test

[4] W. Amos. 2002. *Summary of Chariton Valley Switchgrass Co-fire Testing at the Ottumwa Generating Station in Chillicothe, Iowa: Milestone Completion Report*. NREL/TP-50-32424. National Renewable Energy Laboratory, Golden, CO 8040-3393.

was a learning experience from which emissions conclusions could not be confidently drawn, but from which valuable operational and procedural lessons were incorporated into the planning and execution of the subsequent cofire tests.

Exhibit 15 shows a simple flow diagram for the processing system employed for the first test burn. Numerous improvements were made to the feed handling equipment during testing. Fuel and ash samples were collected and boiler and emissions performance were analyzed to the extent possible.

Exhibit 15 Switchgrass Processing System Flow Diagram for First Test Burn



In addition to valuable equipment and operations-related experienced that was gained, and recommendations for operations during the future test burns, the preliminary findings of First Test Burn were as follows:

- Opacity did not change significantly during cofiring.
- Total particulate matter (PM) and particulate matter with an effective diameter less than ten nanometers ($PM_{10)}$ emissions appeared to decrease (by about 50% each) during co-firing. The large observed decrease in PM_{10} emissions, although desirable, was unexpected. This result warranted further testing.
- A one day stack test indicated that CO emissions appeared to increase. Results obtained using a portable gas analyzer throughout the entire testing period indicated that on the day of the stack test, the boiler was operating irregularly. The portable gas analyzer results suggested that CO emissions did not increase during cofiring on other test days (when stack tests were not conducted). The CO emissions implications of switchgrass cofiring at OGS were not well understood following the first test burn – further testing was required to evaluate air permit implications of cofiring switchgrass.
- Daily-average NO_x emissions appeared to increase by about 6% (as measured by the CEM) during co-firing. This was unexpected due to the fact that the nitrogen content of switchgrass was about 50% of that for the Powder River Basin coal burned at OGS, and reductions or at least no increases in NO_x emissions had been measured during similar cofiring tests at other power plants.

Further emissions testing was required to understand the effect of cofiring on OGS NO_x emissions during steady-state operations.

- Small decreases in SO_2 emissions were observed during cofiring – this was consistent with the lower sulfur content of switchgrass relative to coal and was expected.
- Unburned switchgrass particles, primarily the round nodes located on the plant between adjacent sections of stalk, were observed to be present in noticeable volumes around the edges of the bottom ash settling pond. Some of these nodes were barely charred. While this did not appear to impact the quality of the bottom ash significantly for its present uses (fill, cover, and landscaping), it was an indication that some of the larger diameter switchgrass particles were dropping to the bottom of the furnace before burning, even though there were several rows of coal burners beneath the switchgrass burners.

The primary accomplishment of the first test burn was to demonstrate to plant management and operators that switchgrass cofiring operations could be performed without creating significant nuisance issues with regard to normal plant operations, and without creating significant problems with regard to air emissions or visible fly ash quality. This accomplishment helped in gaining approval and support from Alliant Energy and IPL to continue with the project and begin planning for the next test burn and the associated air permitting and fly ash testing activities.

2.2 Interim Test Burn

The interim cofire tests were conducted during the first two weeks of December 2003. Pre-testing of biomass processing equipment and sampling techniques occurred between November 21 and 26, 2003. A maximum total of 2,000 tons of switchgrass was approved by the Iowa Department of Natural Resources (IDNR) to be burned during the Interim Test Burn time window; however, the project team's expectation was to burn a total of 1,300 tons or less. To meet the objectives of the Interim Test Burn, it was only necessary to burn an estimated total of 781 tons (1,673 bales) of switchgrass during the pre-test and testing periods combined. The average switchgrass feed rate during the December cofire testing was about 8.9 tons per hour, representing about 1.9 percent of the boiler's heat input. The maximum feed rate of switchgrass during the testing was estimated as 11.6 tons per hour. Average plant load during the tests was 95% of full load operation, or about 691 MW (gross). The average gross load during cofiring periods was 686 MW, and the average coal-only load was 696 MW--a difference of only 1.0%. The minimum average load on a test day was 646 MW (89% of full-load), and the maximum was 719 MW (99% of full-load). Soda ash addition rates were maintained constant throughout all required emissions testing. To minimize the variability of coal quality during testing, plant management arranged for all coal supplies during the testing to be from the same mine.

During planning efforts for the Interim Test Burn, the CVBP engineering team worked hard to identify and mitigate potential operational issues that could have a negative impact on the testing. Some of the rented equipment used in First Test Burn was replaced by purchased equipment that, although still considered temporary, was representative of the processing system that would be incorporated into a potential permanent facility in the future if the project enters commercial operation. The newly purchased equipment included the following: a bale infeed conveyor, twine remover, debaler, debaler outfeed conveyor, larger airlocks, and meter bin modifications. This new equipment, and the experience gained during First Test Burn, allowed more problem-free operation of the switchgrass processing system during the Interim Test Burn.

Data sampling procedures were also refined and more manpower was made available for collecting test performance data during the Interim Test Burn. Improved process control and automated data collection capabilities were installed in the biomass processing facility, including installation of biomass feed rate and on/off sensors that were tied into the main data acquisition system at OGS. This upgrade allowed automatic collection of biomass feed rates, on a minute-by-minute basis, corresponding to the emissions measurements collected by the Continuous Emissions Monitoring System (CEMS) at OGS and by the stack emissions test contractor. Emissions data from the 30-day period preceding any switchgrass firing was also collected from the OGS CEMS for comparative purposes.

The project team collected coal, switchgrass, fly ash, bottom ash, and economizer ash[5] samples for each test day, with switchgrass samples taken hourly during cofire testing. The following analyses were performed by Consol Energy (Pittsburg, PA) for daily coal and switchgrass fuel samples: ultimate and proximate analysis with heating value; sulfur, chlorine, alkali, and RCRA trace metal content[6]; major ash elements; and ash fusion temperatures. Summary data for this laboratory testing is provided in Appendix B. Emissions during the test period were estimated using CO2-based F-factors that were based on the coal and switchgrass sample analyses from each day and the heat-input rate for switchgrass. In addition to emissions measurements using the CEMS, GE Mostardi Platt[7] measured CO, O_2, CO_2, PM, PM_{10}, Hg, and Cl_2 emissions at various periods during the testing. A portable combustion analyzer was also used to continuously monitor CO emissions throughout the testing period.

[5] Fly ash is fine ash particles that escape the boiler and are collected. Bottom ash is composed of denser particles that are collected at the bottom of the boiler. Economizer ash accumulates and is collected from below the economizer.

[6] RCRA, which stands for Resource Conservation and Recovery Act, is a major piece of environmental law that among other things created regulation of hazardous wastes including toxic metals.

[7] Results from the GE Mostardi Platt report will only be summarized in this report. Complete details of the GE Mostardi Platt test results are available in the following report, which has been provided under separate cover to IDNR: GE Mostardi Platt Report M22E0343A, *Particulate and Gaseous Emissions Study*, Elmhurst, IL, January 20, 2004. (This report may not be available for public distribution.)

The primary accomplishments of the Interim Test Burn and the ensuing analysis and reporting efforts were:

- Continued demonstration that switchgrass cofiring could be implemented at OGS with no significant apparent detrimental effects to operations or equipment, and demonstration that the improved processing system could, with noted improvements, operate reliably to provide a stable and predictable supply of processed biomass to the OGS boiler.

- On the basis of the emissions data collected during the test, the Iowa DNR approved and permitted the construction and operation of a permanent biomass processing facility at OGS.

- On the basis of the fly ash sampling activities and subsequent testing and reporting, the Iowa Department of Transportation provided written approval for fly ash from switchgrass cofiring operations (with up to 5% heat input from switchgrass) at OGS to be used in concrete applications in the state. This approval made the long term continuous test burn possible and represented the removal of a significant barrier to potential future commercial operations.

2.3 Long-Term Test Burn

The Long Term Test Burn was a 3-month test burn of switchgrass with coal aimed primarily at investigating the potential long-term impacts of switchgrass cofiring at Ottumwa Generating Station. The test was also treated by project partners as a dry run for commercial operations, during which the project team led by Chariton Valley RC&D, Inc., Prairie Lands Bio Products Inc., and Alliant Energy / IPL, operated as if commercial operations had begun. All data collection, environmental and performance reporting, communications, and invoicing and payment for biomass fuel supplies were conducted under a short-term contract that was used as a model for commercial operations. The test burn officially commenced on February 16, 2006 and ended May 12, 2006. By the end of the test burn, the Chariton Valley Biomass Project team had accomplished the following:

- Delivered, processed, and burned 31,568 bales of locally-grown switchgrass totaling 15,671 tons as renewable fuel for generating electricity at Ottumwa Generating Station (OGS).

- Generated an estimated 19,607,000 kilowatt-hours of electricity from the renewable switchgrass fuel. That was enough electricity to provide 100% of the electricity needs for an entire year for over 1,874 average Iowa homes. This was a world record for electricity generation from switchgrass.

- Processed and burned switchgrass as fuel at OGS for more than 1,675 hours. Processing hours per day improved significantly since the beginning of the test burn, with the facility operating without downtime nearly continuously throughout the last month of the test burn.

- Reduced emissions of sulfur dioxide (SO2) from OGS by about 62 tons due to the extremely low sulfur content in switchgrass. The coal used as fuel at OGS is low-sulfur coal, but not as low in sulfur as the switchgrass which contains only about 0.1% sulfur (by weight).

- Reduced emissions of carbon dioxide (CO2), the primary greenhouse gas, by a total estimated amount over 50,800 tons through reductions at the power plant, and because the switchgrass absorbs carbon dioxide from the air during its growth cycle and stores a portion of the absorbed carbon in its deep root system—this also improves the soil conditions on the fields where the switchgrass is grown.

- Generated about 626 tons of fly ash which was approved for sale from the power plant for use in concrete and other valuable byproducts. This ash is what is left over from the switchgrass after it is burned in the boiler, and is collected at the power plant along with ash produced from the coal.

- Demonstrated that the processing system designed, installed, and operated by the project team throughout the test burn could be operated reliably at and above its designed process rate of 12.5 tons per hour, especially if the switchgrass delivered to the facility contains moisture contents of 12% and under. The average moisture content of switchgrass burned throughout the test burn was about 13%.

- Replaced about 12,060 tons of coal purchased from Wyoming with renewable switchgrass that was planted, grown, harvested, stored, delivered, and processed by local Iowa farmers.

- Generated an estimated 19,600 Renewable Energy Credits (RECs) that received independent third-party certification under Environmental Resource Trust's *EcoPower* program. This program certified the amount of power generated during the test burn that resulted from a renewable energy source, and would be a necessary step in allowing a commercially operating project to market the RECs to companies, government organizations, and/or residential consumers who are willing to pay a small premium to ensure that a portion of their energy purchases go to a renewable power generator. Purchasing these RECs can help companies and government organizations meet their environmental goals.

- The project team, and in particular the staff and management who operated the processing facility, earned praise for their performance throughout the test burn from Alliant Energy and IPL plant staff. This was a very important accomplishment leaving the door open for possible commercial operations in the future when economic conditions are favorable to the contract parties.

- The extensive work performed to assess the potential long term impacts of cofiring switchgrass at OGS demonstrated that there were no significant detrimental impacts to plant operations or equipment within the range of switchgrass heat input used during the test burn or planned for possible future commercial operations.

In addition to its demonstrated application for power applications, the project team believes the processing system demonstrated for this project would also be well-suited for application in facilities that would create ethanol and/or other co-products from baled switchgrass or other agricultural forms of biomass.

3 Description of Facilities

The purpose of this chapter is to provide a summary and description of the facilities that were installed and used to carry out the objectives of the project. Straw storage facilities at Ottumwa Generating Station (OGS) and remote from the site will be briefly discussed. Most of the attention in the chapter will be given to the new switchgrass processing facility and the processing equipment located within that building which was used for the Long Term Test Burn (LTB) and is available for potential future operations. Controls and communications, data acquisition, and equipment operation and costs will also be discussed briefly. More detailed descriptions of the operational experience and design considerations for the processing system are provided in Chapter 4.

3.1 Remote Storage Buildings

A total of thirty facilities were used over the course of this project for switchgrass storage. Details on each facility are provided in Chapter 1, Section 1.3. Of the thirty facilities, eight were existing facilities, twenty were built at least in part for this project and their construction was cost-shared by local farmers, and two were used for storage to some degree but were not built specifically for storage purposes (those two facilities were the buildings used for processing switchgrass during the project's test burns). Twenty-six of the storage facilities are located remotely from OGS, on local farms in proximity to the switchgrass fields that were harvested for the project. Due to the harsh Iowa weather and the length of storage period required for the project, in some cases requiring the baled switchgrass to be stored for several years while the biomass inventory to accomplish the Long Term Burn was built up, all of the remote storage facilities were fully-enclosed metal buildings similar to the one shown in Exhibit 10 in Chapter 1. A total storage capacity of an estimated 24,495 tons was used during the project. The weighted average distance of the stored material to OGS was about 31 miles. Of the remote storage buildings that were built in part for the project, eleven had a 16 foot high storage bay, five had a 20 foot high bay, and one each had bay heights of 18.5 and 30 feet. The combined storage capacity of the remote storage facilities was about 17,800 tons. At least some portion of this remote storage capacity would be available for storage purposes if a commercial biomass cofiring operation is pursued at OGS.

3.2 Storage Facilities at OGS

There are three storage facilities located onsite at OGS. Locations of these facilities with reference to the OGS main building can be seen in Exhibit 2 and Exhibit 3 in Chapter 1. The straw storage building on the east side of the OGS facility is the original location for the processing system (the "Biosilo"). The additional two on-site storage buildings are the "Hoop Building" and the "Straw Palace." Storage and construction characteristics for these buildings are provided in Exhibit 8 in Chapter 1. The total combined storage capacity of these buildings is about 6,600 tons.

3.3 Biomass Processing Facility

The Biomass Processing Facility was built after completion of the Interim Test Burn to allow a three month continuous test. The Biomass Processing Facility houses all of the switchgrass processing equipment and is located on the west side of the OGS property, across the fence from the gated portion of the plant property. This location was preferred by Alliant and the project team because it allowed the construction activities, biomass facility traffic, and the flow of switchgrass delivery traffic to all occur outside of the plant gate. This was preferable for plant security purposes and to minimize the every-day interference of biomass operations on existing operations at the plant. Exhibit 16 shows several bale delivery trucks waiting in front of the processing facility to be unloaded during the Long Term Test Burn. Exhibit 17 through Exhibit 19 show facility and processing system drawings and schematics for the biomass processing system that was designed and installed for the LTB. Exhibit 21 and Exhibit 22 show the process control and automation system that was installed in the new facility and utilized throughout the LTB. The text below describes the function and operation of the processing system and its controls.

Exhibit 16 Baled Switchgrass Arriving by Flatbed

The controls and equipment arrangement in the “Biosilo” processing facility that was used for the First and Interim Test Burns were not sufficient to allow a long term continuous test that would emulate a commercial operation and allow the type of uninterrupted operations that were required for evaluating long term operations impacts and performance issues. Operations in the “Biosilo” could be sustained for short duration tests (4 to 8 hours) required for collecting emissions data or fly ash samples, but only through the use of a crew of operators that was in excess of what would be economical for a long duration continuous test or commercial operations. A crew of up to six people was required to operate and maintain the processing system during the Interim Test Burn and to quickly recognize and clear material bridging problems as they occurred. An annotated presentation of the equipment used during the Interim Test Burn is provided in Appendix B. Based on the experience gained with the processing system during the Interim Test Burn, an improved processing system with automated controls was designed and implemented for the Long Term Test Burn (LTB).

To reduce the costs of the biomass processing equipment for the Long Term Test Burn, most of the equipment from the Interim Test Burn was incorporated into the improved processing system. The bale conveyors were modified and re-used, and a few new conveyor sections were added to perform specific functions including: 1) merging bales from the twin bale infeed conveyor into a single line of bales to allow feeding one bale at a time into the debaler, 2) a bale sensing conveyor that automatically measured bale weights and moisture contents, and 3) a bale reject conveyor which could automatically remove bales that did not meet the fuel quality specifications required by the fuel supply contract from the processing line. In addition to portions of the conveyor system from the Interim Test Burn, the following equipment was re-used from the Interim Test Burn processing system: the bale De-Stringer, the Debaler, the inclined conveyor between the Debaler and the attrition mill, the attrition mill (the "Eliminator"), the combination cyclone/baghouse, the tube conveyor ("tube-veyor") from the baghouse to the surge bin, the surge bin, and the positive displacement blowers that pneumatically conveyed processed switchgrass from the processing facility to the OGS boiler.

3.3.1 Facility and Processing System Description

Exhibit 17 shows plan and elevation drawing views of the biomass processing facility that was built for the LTB. Additional site and facility drawings are provided in Appendix A. Exhibit 18 provides a simplified schematic of the processing facility. There are two primary differences between these Exhibits and the facility as it was built: 1) two processing lines are shown on the drawings, but only one has been built to date, and 2) the high-efficiency cyclone which receives processed switchgrass from the second milling process is shown in the Exhibits as being under roof, however in order to save costs on facility construction the roofline was built below the cyclone. Referring to Exhibit 18, the dimensions of the facility are roughly 233 ft long x 70 ft wide x 36 ft high. There are roll-up, drive-through truck doors on both walls of the bale unloading end of the facility. These doors allow trucks to pull into the building, be unloaded, and exit through the opposite side of the building without backing up. Indoor unloading was especially convenient during rain, snow, night, or extremely cold conditions. A control room is located in the center of the processing facility on the second floor. Windows were installed around the entire perimeter of the control room to allow the lead operator / shift supervisor to observe all areas of the facility from the control room. The motor control center is located on the first floor beneath the control room. The facility was designed to accommodate two identical bale processing lines, however only one line was installed for the LTB. The second processing line, shown as dashed or phantom lines in Exhibit 17 and Exhibit 18, would operate in a similar manner to the first processing line but would supply ground switchgrass through two separate pipes to opposite corners of the West half of the OGS boiler furnace. The existing processing line supplies ground switchgrass to opposite corners of the East half of the furnace (as shown in Exhibit 5, Chapter 1). During the LTB, part of the area left vacant because the second processing line had not been built was used as temporary bale storage to allow floor operators to load bales from indoor storage during rain or cold conditions.

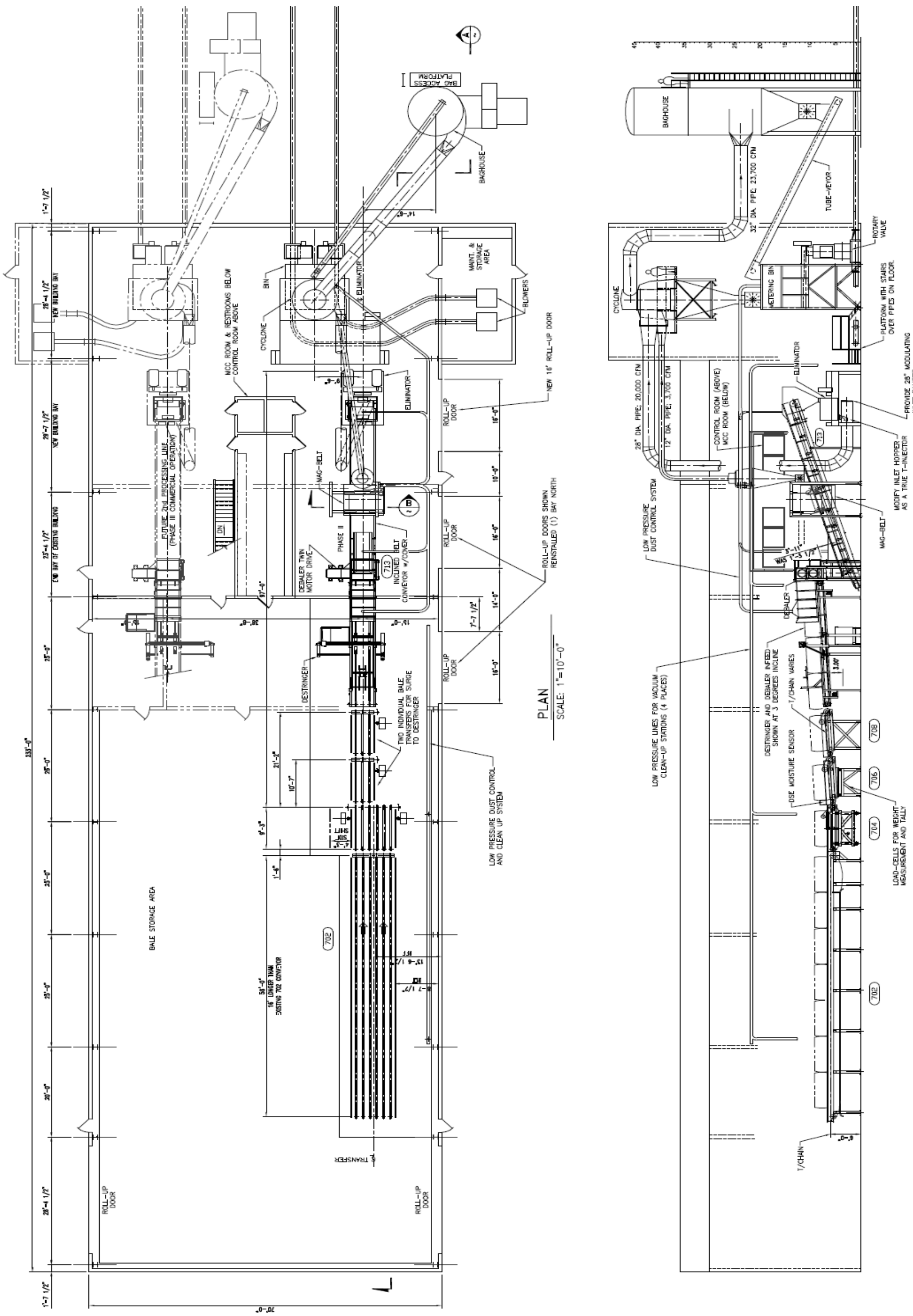


Exhibit 17 Biomass Processing Building Drawing

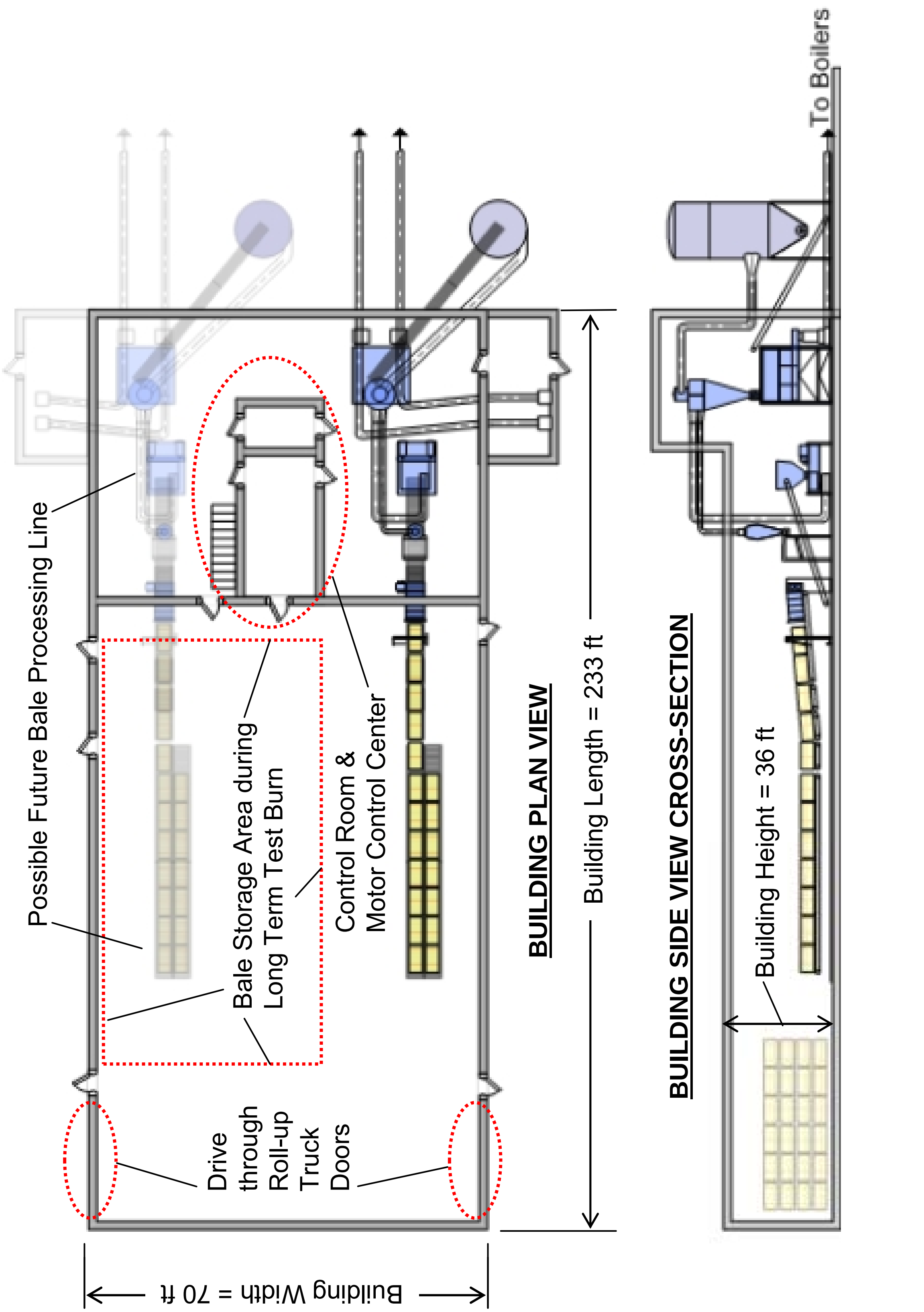


Exhibit 18 Biomass Processing Building Simplified Layout Drawing

Exhibit 19 shows plan and elevation views of the switchgrass processing equipment in the Biomass Processing Facility. Additional details and photos of each major piece of equipment are provided later in this chapter. General operation of the system was as follows. Delivery trucks for the full day's processing requirements typically arrived early in the morning and bales were staged by the truckload in the yard outside the processing facility. A typical daily processing rate in the final month of the test burn was about 250 tons, requiring morning deliveries from about 12 truckloads to meet the full day's process requirements. The 3 ft high x 4 ft wide x 8 ft long bales (nominal dimensions) were typically delivered on 53-foot length flatbed trailers. Each truckload carried 42 bales, arranged in three layers, with each layer consisting of bales in a 2 wide by 7 long arrangement. Bales on one or both ends of the trailer extended beyond the ends of the trailer in order to accommodate the seventh row of bales.

Referring to the schematic diagram in Exhibit 19, switchgrass bales staged on-site were loaded onto the twin bale conveyor using a teleboom loader with a four-bale grapple. The twin bale conveyor allowed for up to 14 bales to be placed on the conveyor at once, in a 7 long by 2 wide arrangement. Bales were fed from the twin bale conveyor onto the bale merge conveyor one pair at a time. The merge conveyor feeds one bale forward to the bale sensing conveyor, then pivots to line the second bale up with the bale sensing conveyor. Next, the merge conveyor feeds the second bale onto the bale sensing conveyor and then returns to its home position empty and ready to accept a new pair of bales from the twin bale conveyor.

While on the bale sensing conveyor, each bale is weighed and moisture content is measured using a microwave sensor—this information is fed into the control system database and is stored for monthly billing purposes. The bale weights and moisture content were among a set of six parameters that was transmitted in real-time to the OGS data acquisition system to allow OGS staff to independently review results and incorporate the biomass feed information into the plant's performance and operations database. Moisture content measurements were used as a quality control. Bales with elevated moisture levels (above 20% average moisture) could be automatically removed from the process line with the bale rejection conveyor.

Bales within quality control limits would pass through to the De-Stringer, where twine from the bales was automatically cut, removed and dropped into a storage bin for later removal from the site. The conveyor controls were designed to crowd each bale tightly against the prior bale—this prevented the bales from springing apart when the twine was cut, and encouraged a more even flow into the Debaler. From the De-Stringer, bales pass through a two-stage milling process. Feed rate was measure in feet per minute on the Debaler infeed conveyor and calculated to tons per hour (based on the bale weight measurements) as the bales were fed through the Debaler. The Debaler was a horizontal hammer mill from Warren & Baerg and was driven by two 200-hp motors, each driving a rotor with a set of swinging hammers. The rotating hammers chopped the material on the leading edge of the bale and the ground material remained in the debaler until it passed through a set of screens mounted at the rear of the mill, opposite of the bale infeed. Screens with two-inch diameter holes were considered to be the optimum screen size for this processing system and material.

Once it passed through the Debaler screens, the debaled switchgrass dropped onto an inclined belt conveyor, then passed under a magnetic belt conveyor which separated large pieces of metal from the debaled material. The material was then conveyed to the inlet of the attrition mill (the “Eliminator”) for secondary milling. The “Eliminator” was driven by two 300 hp motors. After passing though this second mill, the switchgrass had been processed to roughly a 1/8” minus size. Photos of processed samples obtained from the Debaler and “Eliminator” using different debaler screen sizes are provided in Appendix I. Due to the nature of operation of the “Eliminator,” the final product sizing was fairly independent of the Debaler screen size—the Eliminator would produce a fairly consistent product and its load would increase as the size of its infeed material increased.

A 20,000 cfm, 100 hp baghouse fan was used to pull ground switchgrass from the “Eliminator” discharge. The material was pneumatically conveyed to a high-efficiency cyclone located between the “Eliminator” and the baghouse. The cyclone separated the heavier particles from the air stream and dropped them through a rotary airlock into the processed material surge bin. The remaining fine material and air was pulled through a combination cyclone/baghouse (a “Big Round Filter” from Camfil Farr) which removed the fine dust from the air stream. The fine dust collected by the baghouse was dropped through a rotary airlock onto a fully-enclosed tubular conveyor which conveyed the material via belt to the same surge bin where the material exiting from the cyclone was deposited.

Once in the surge bin, the switchgrass was ready for transport to the OGS boiler. Two screw feeders located lengthwise on opposite sides of the surge bin bottom conveyed the material to two rotary airlocks which fed the processed switchgrass into the pneumatic conveyance pipes leading to the boiler. Two 150 hp positive displacement blowers, one for each conveyance pipe, each provided about 3,000 cfm of air at pressures up to 7 psig (typical conveying pressure was 4.5 psig) to convey the processed material to the boiler.

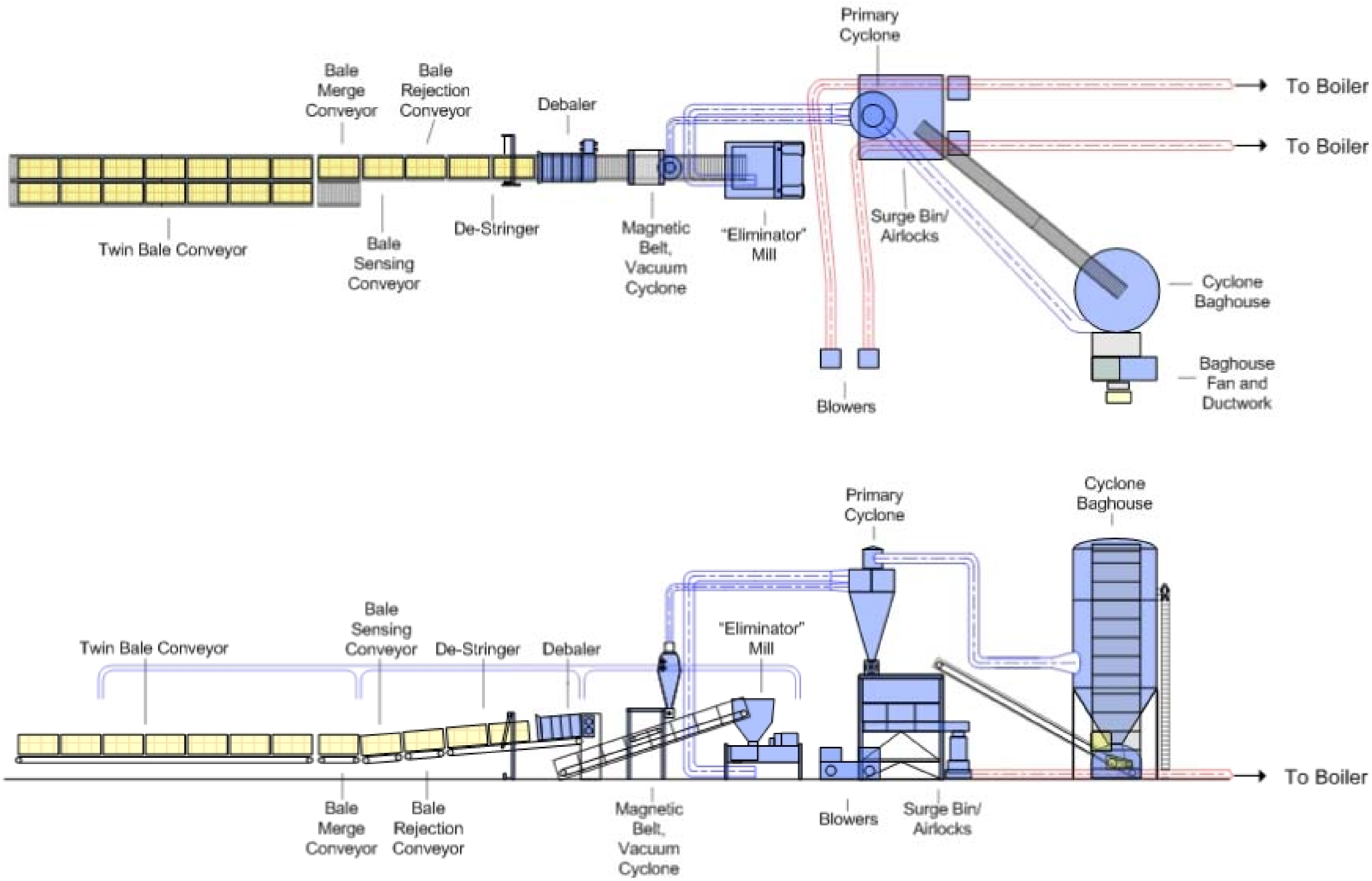


Exhibit 19 Biomass Processing Equipment System Schematic

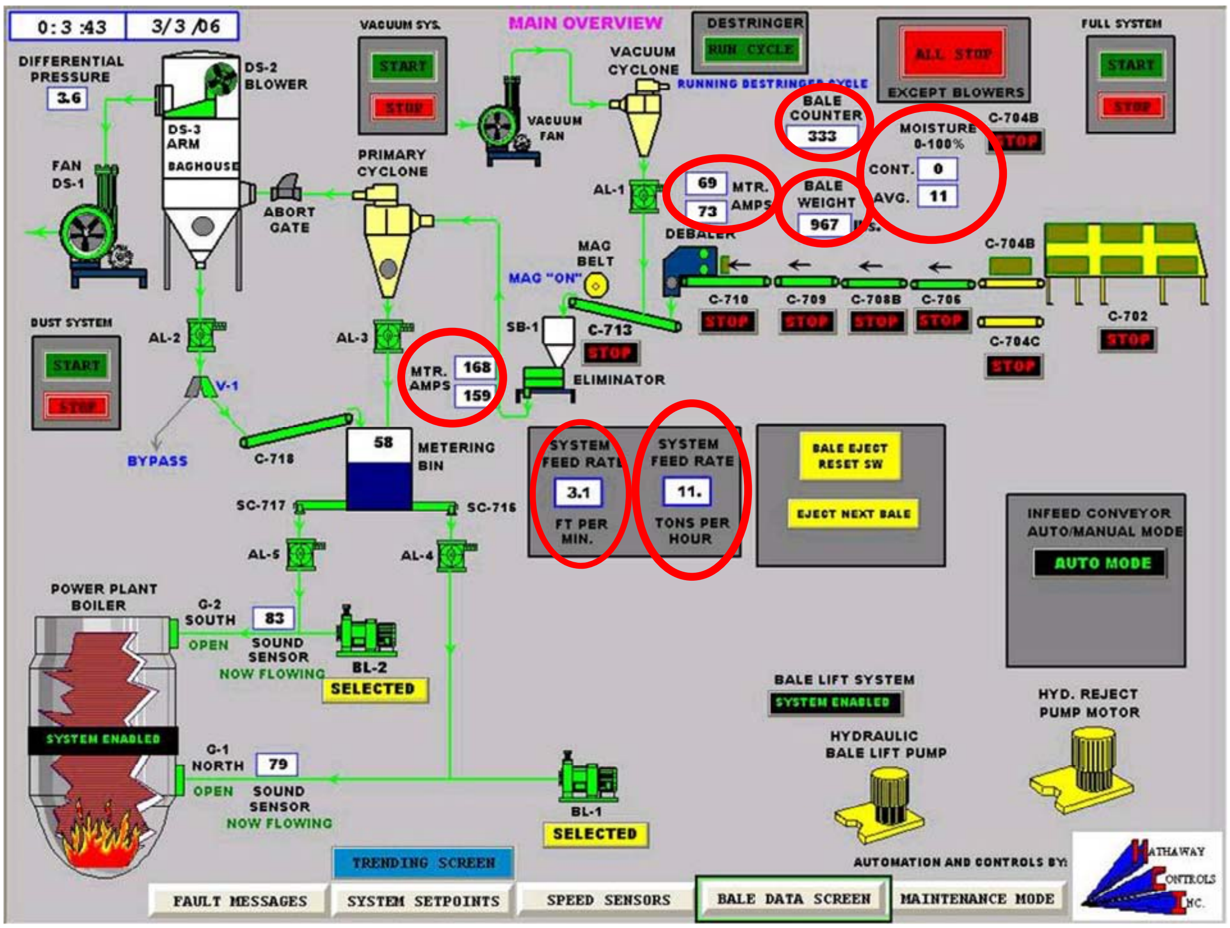
3.3.2 System Specifications and Controls

The processing system was designed to operate at an average feed rate of 12.5 tons per hour and was demonstrated at rates well above that (up to about 20 tons per hour) when uniform, low moisture content, well-packaged bales were being processed. On average, for the material received and processed throughout the LTB, the production rate was closer to 10 tons per hour (based on the final month of processing)—that rate includes outage and stoppage times to perform equipment upgrades and maintenance, to clear material plugs when they occurred, and process rate reductions experienced when the process line was waiting for bales to be fed into the process line during periods when low density or poorly packaged bales were delivered. A second processing line could be installed at the Biomass Processing Facility if warranted. This would increase the total design feed rate to 25 tons per hour, with a conservative expectation to allow delivery of an average of about 20 tons per hour based on experience to date at this facility with an identical process line to the first line. Suggestions on process design changes that could increase the average feed rate are provided in Chapter 4.

One of the primary improvements in the biomass processing system between the Interim Test Burn and the Long Term Test Burn was the design and installation of an automated control system. During the Interim Test Burn, system operators were required to manually step through the entire start-up and shut-down sequences. In addition, slight differences in bale properties or equipment operation would remain un-noticed until a system shutdown was necessary due to excessive material bridging to the point where material was either spilling onto the floors due to an upstream plug, or material was severely packed inside the Debaler. Automatic controls would either sense a problem about to occur and automatically take evasive measures or warn the lead operator of a pending problem. Either situation typically required an extended shutdown and clean-up process. Based on experience gained during the Interim Test Burn and a series of process equipment tests performed in August 2004 (summarized in Appendix I), a fully automated control system was designed to allow the control system to sense potential processing problems and automatically adjust in time to allow the problem to dissipate before a system shutdown occurred. The project's engineering design team, working closely with Hathaway Controls Inc., designed and implemented the control system. By mid-way through the LTB, the control system was operating well enough that the system could operate unmanned in the control room for extended periods of time without system shutdowns—operators were still required to ensure that the bale infeed lines were fully stocked with bales, for general clean-up and maintenance, and to assist with occasional problems on the conveyor lines. This automated operation allowed time for the lead operators / shift supervisors to perform duties other than full-time monitoring of the processing system control screen and significantly reduced system downtime.

Exhibit 21 and Exhibit 22 show the types and locations of control sensors and corresponding controlled devices located throughout the processing system. An additional drawing and control sensor and motor table are provided in Appendix C. Exhibit 20 shows an example of the main biomass processing system control screen during system operation, and a sample screen image of each screen available in the operating system is provided in Appendix C along with a brief explanation of the contents of each screen. Several key operator indicators are circled in Exhibit 20: daily bale counter, bale weight indicator, moisture content indicator, feed rate indicator in tons per hour and conveyor speed in feet per minute, and motor amp readings for each rotor motor on the Debaler and "Eliminator." Start-up and shut-down sequences were programmed to be fully-automated, including emergency shutdowns. Once permission was granted by the OGS control room operator to start the biomass system, the biomass control room operator would initiate the start-up sequence using a single button on the biomass control room touch screen.

Exhibit 20 Main Biomass Process Control Screen



Photoeye sensors and dry contact limit switches were used throughout the bale conveyor system to detect the locations of bales. The emitter and receiver in photoeye sensors can detect the presence of an obstacle if the sensing beam gets interrupted, in this case by a bale advancing to a certain location on the conveyor. Photoeyes were used on the twin bale conveyor to signal when the conveyor was empty and needed to be loaded, and also to prevent bales from being dumped off of the rear of the conveyor when an operator was reversing the conveyor feed direction. When the conveyor was down to the last pair of bales, the photoeye would trigger a strobe light that would alert the floor operator to reload the conveyor. Mechanical devices were mounted elsewhere throughout the conveyor system (on conveyors C-702, C-704, C-706, C-708, C-709, and C-710) to detect the presence of a bale and trigger a signal using a dry contact limit switch. Based on the detected positioning of bales on the conveyor line, the control system was programmed to automatically advance bales through the process line as bales were processed in the Debaler. Reversing variable frequency drives were installed on all bale infeed conveyors. The control room operator could take the system out of automated control at any time if he needed to manually manage bale infeed or reverse bales on the conveyor to perform maintenance or to address feed problems.

The bale sensing conveyor (C-706) measured bale moisture content using a microwave sensor and measured weight using load cells mounted to the conveyor table. A strobe light and audible alarm were installed on the bale reject conveyor (C-708) to alert floor operators when a bale had been rejected and therefore needed to be reclaimed off of the bale reject platform. A limit switch on the De-Stringer conveyor was used to count bales and provide that information to the control system database.

Current transducers on each rotor motor on the Debaler and “Eliminator” were used to measure motor currents and reduce process feed rates momentarily if motor loads exceeded limits that were predictive of pending material flow problems. The project team performed process tests in August 2004 to identify measurable conditions which preceded system shutdowns (see test summary results in Appendix I) and used that information in the design and programming of the control system in the biomass processing facility to reduce system shutdowns and to reduce the need for constant operator monitoring. Bale feed rates would gradually be increased to the operator’s target feed rate once the motor loads had returned to acceptable levels.

Speed sensors were installed on the rotating shafts of each airlock and screw feeder in the plant to provide feedback to the control room operator if the shaft stopped or slowed rotation to a level that would indicate a problem. Speed sensors were installed on all rotary airlocks, both metering bin crew feeders, and on the inclined conveyor drive shaft. Ultrasonic plugged flow sensors were installed in areas of the process that were prone to developing material plugs (the outlet chute from the debaler, and the inlet chute to the “Eliminator”). Each plugged flow indicator installation requires two ultrasonic sensors to be installed facing each other on opposite walls of the chutes. When the material rises to the level of the sensors or exceeds it, a plugged flow indication is sent to the control system. The sensors were tuned so they would not indicate plugged flow during normal flow conditions.

Since the “Eliminator” mill operates with very high rotational speeds, a vibration sensor was installed on the housing of the mill to provide an early warning of potential problems in the “Eliminator.” Door switches were designed into the system for installation on all Debaler and “Eliminator” maintenance access doors to sense when the doors were opened, to shut the processing system down and prevent it from operating if the doors were mistakenly opened during operations; however, these were not installed due to budget constraints.

Air pressure sensors were installed in the baghouse and on the pneumatic transport lines from the biomass processing facility to the OGS boiler. The purpose of the sensor in the baghouse was to indicate whether there was a material blockage problem in the baghouse—this did not occur during the Long Term Test Burn, however it did occur several times during previous testing when the blower that periodically cleans the bags had not been turned on. The purpose of the pressure sensors in the transport lines to the boiler was to protect the blowers by shutting them down if a severe blockage occurred during operation, or to momentarily stop material feed into the line to allow an increased pressure condition to be cleared. Increased backpressure in the transport line and larger swings in line pressure were observed when conveying higher moisture content material. Plugged lines did not occur during the testing; however, when restarting the system after an emergency shutdown occurred while there was still material in the transport lines, several attempts to restart the system would typically be required because the high pressure sensor would stop the system during the first several attempts until the lines were clear enough to allow continued operation.

Ultrasonic sensors were installed on each pneumatic transport line just downstream of the rotary airlocks which feed processed material into the transport lines. These sensors were tuned to indicate whether there was flow in the line by providing an on/off indication to the control system/operator. Finally, an ultrasonic sensor was installed in the surge bin to provide the lead operator with an indication of the level of material that had collected within the surge bin. The system operator could set a material depth, in inches, that would be allowed to accumulate before material feed to the debaler and all downstream equipment would be temporarily suspended to allow the level in the surge bin to recede or for a feed problem to be addressed. This and all other adjustable control system parameters could be modified through a single control input screen in the operating system (shown in Appendix C, on the “System Setpoint Screen for Process Facility Control System” page).

Finally, video cameras were installed at key locations along the process line to allow the control room operator to view conditions in those areas without leaving the control room or the operator’s workstation. Cameras were mounted to show: the De-Stringer, the inlet to the “Eliminator”, the outlet from the baghouse, and the outlet from the cyclone. These were locations where interruptions in process activities or material flow would be most evident. The control room operator can view the bale storage and loading area inside the building from his workstation, so no cameras were required for that area.

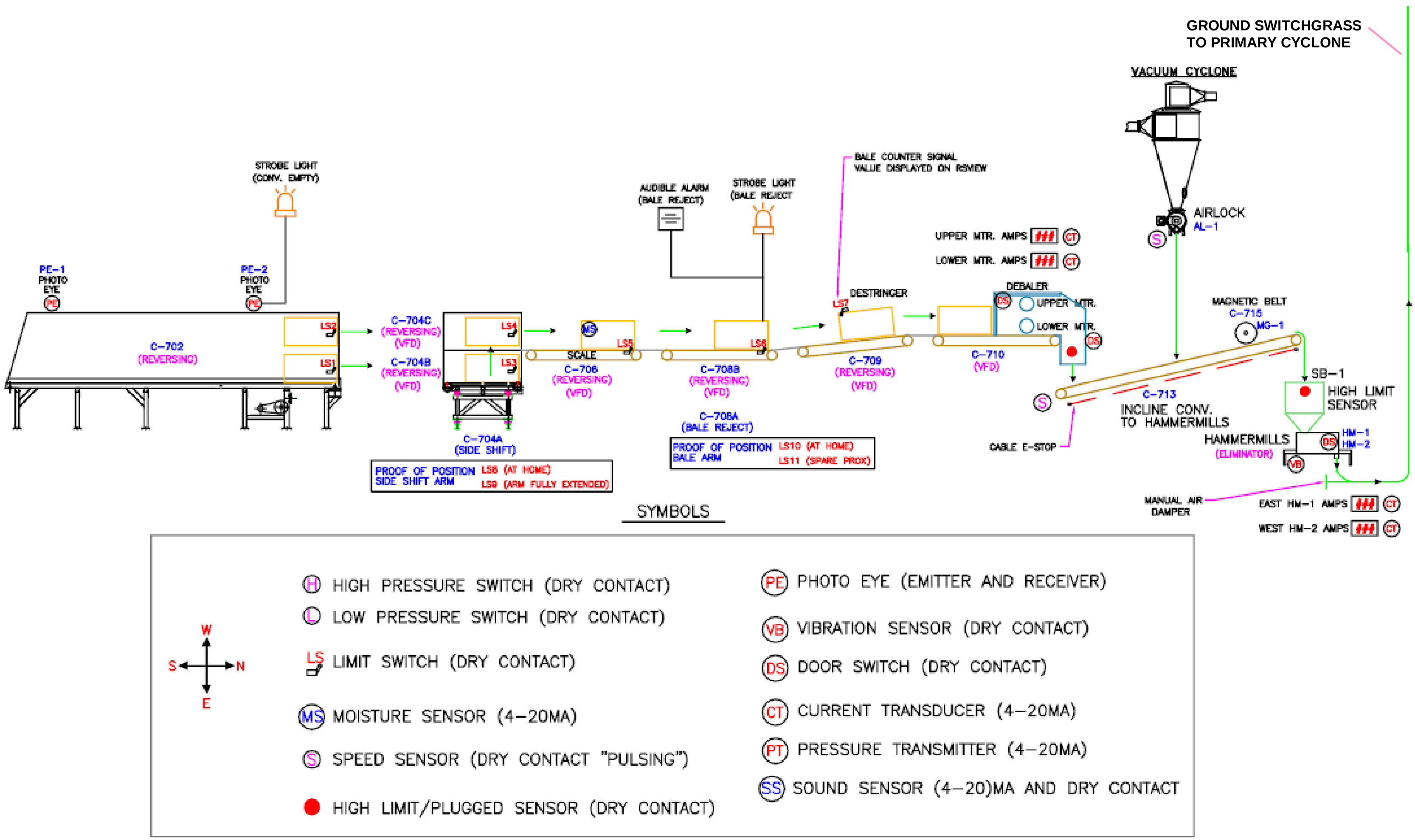


Exhibit 21 Processing System Flow Diagram and Automated Control System Sensors (Figure 1 of 2)

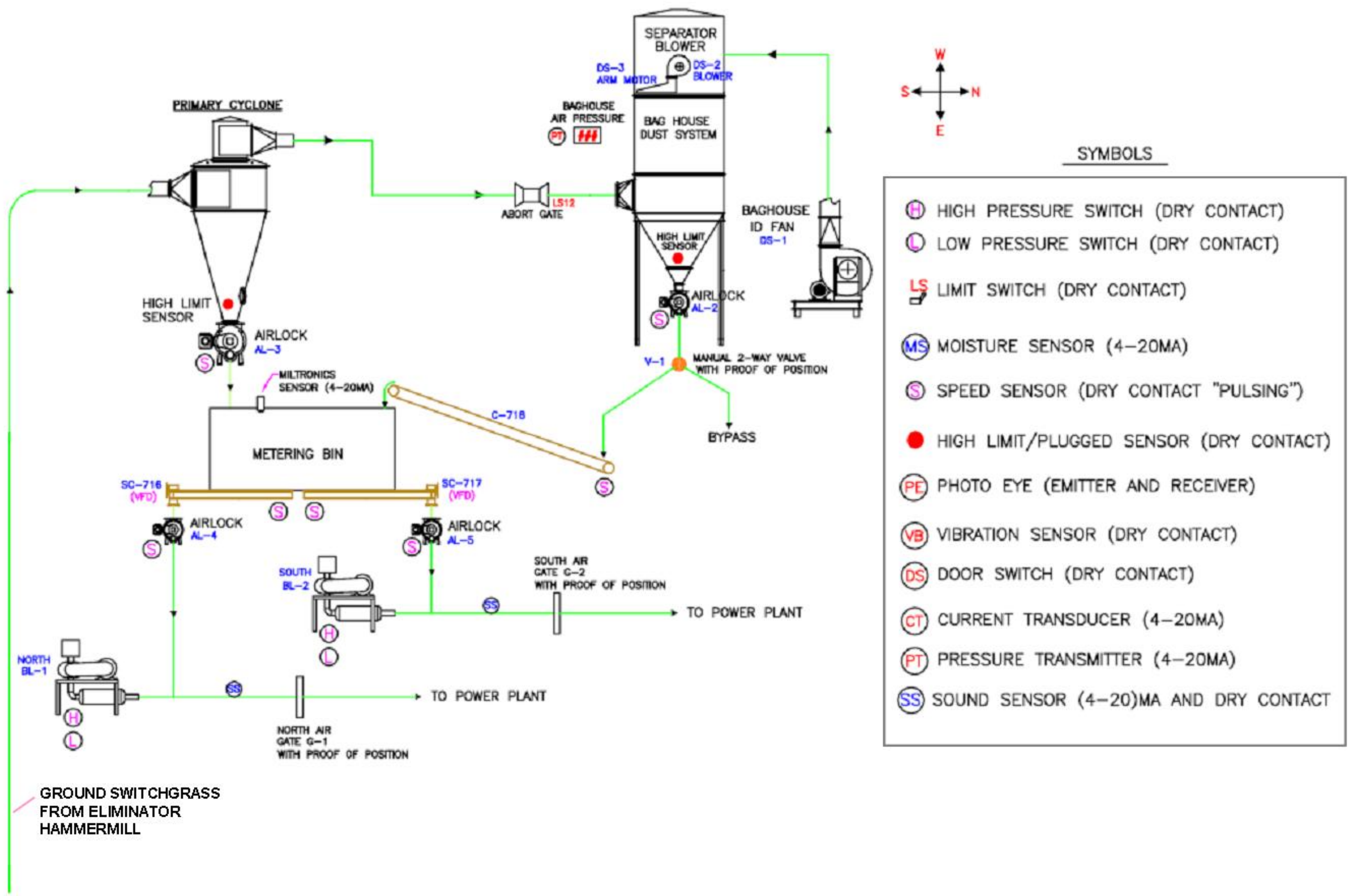
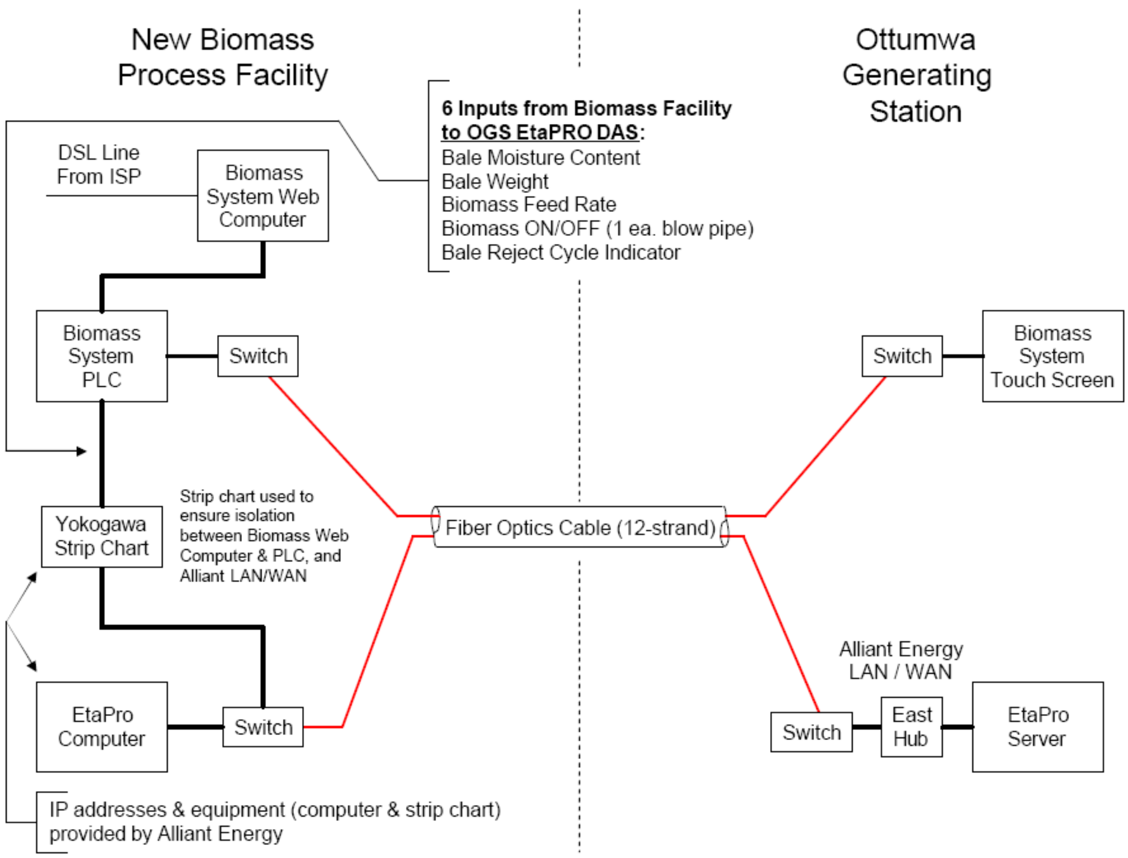


Exhibit 22 Processing System Flow Diagram and Automated Control System Sensors (Figure 2 of 2)

3.3.3 Interface with OGS

Exhibit 23 shows the communications that were installed between the control systems at the Biomass Processing Facility and OGS. During construction of the Biomass Processing Facility, fiber optic lines were installed to connect the operating system at OGS to the control system at the Biomass Processing Facility. The fiber optic lines provided a network connection that enabled a computer to be located within the Biomass Processing Facility control room and connected to the OGS network. Because high speed internet access was not readily available to the Biomass Processing Facility by other means, that connection would allow high speed internet access to the biomass facility. The network connection was installed and tested to confirm functionality, but was not fully utilized due to post-911 security concerns with allowing a third-party to access the Alliant network. To allow continuous feedback of key performance parameters at the biomass facility to the OGS data acquisition system while maintaining isolation from the OGS network, data signals were routed through a strip chart recorder.

Exhibit 23 Communications with Ottumwa Generating Station



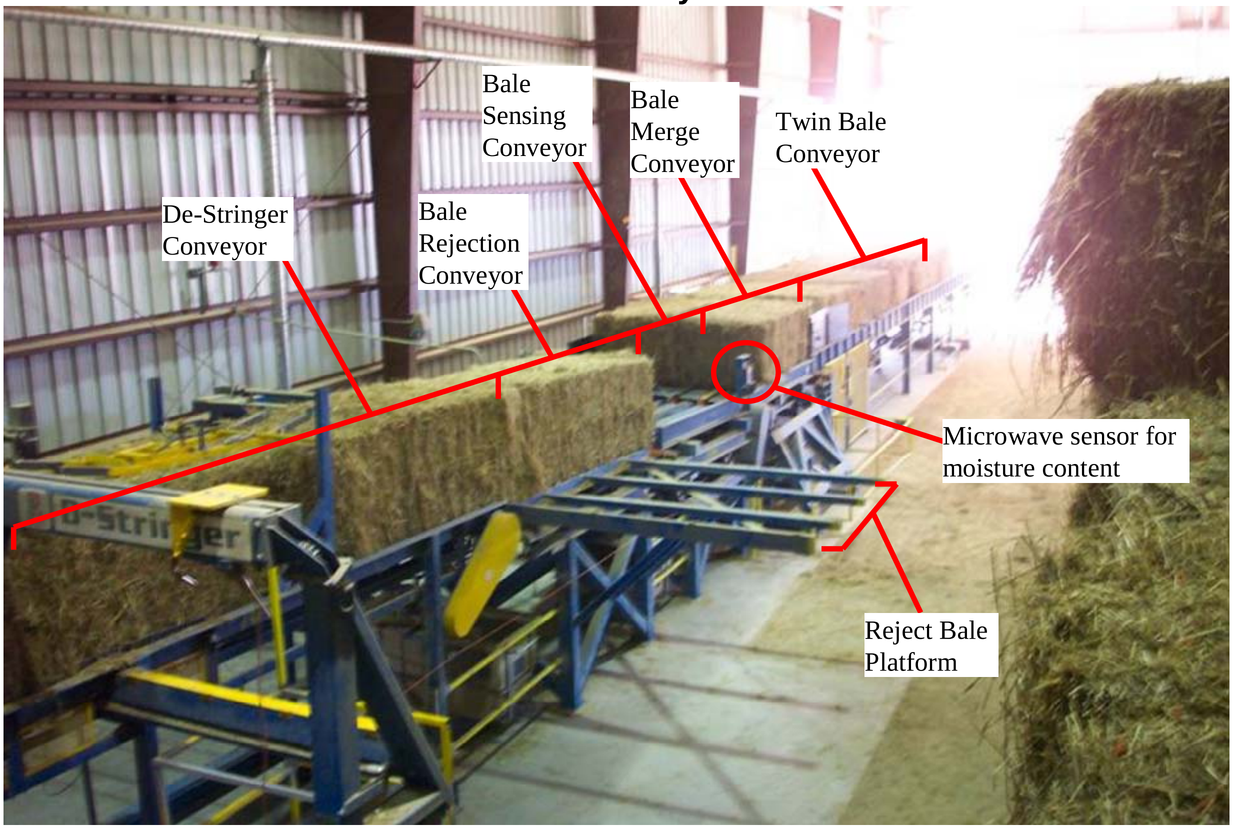
Six key performance parameters from the switchgrass facility were continuously fed into the OGS data acquisition system to allow Alliant Energy performance engineers and OGS staff to independently monitor switchgrass operations and impacts on the plant (in real-time, or saved in the plant's data acquisition system database for analysis at a later time period). Those parameters were: bale weight, switchgrass feed rate (tons/hr), bale moisture content, switchgrass feed on/off for each pneumatic supply line, and bale reject conveyor cycling to record when off-spec bales were rejected. This allowed Alliant/IPL staff to monitor operations at the biomass processing facility in a manner similar to other plant systems.

A touch screen for the biomass system was installed in the OGS control room to allow OGS control room operators to enable or disable the biomass operations at will. OGS and biomass facility lead control room operators would coordinate on normal start-up and shutdown procedures via telephone. Automatic controls were also installed to stop operations in the biomass processing facility based upon several conditions: 1) an emergency condition at OGS which required immediate shutdown of the boiler, or 2) a reduction of boiler load below fifty percent capacity. An emergency shutdown would immediately close the gate valves to the biomass burners and shut down the entire biomass processing line without allowing time to purge the 1500 foot pneumatic biomass transport pipes of biomass within the lines. A controlled shutdown would allow several minutes for the shutdown process, allowing the biomass system to stop process feed, empty the conveyors, and empty the pneumatic transport lines in a controlled manner before shutting down operations.

3.3.4 Brief Equipment Descriptions and Operation

This section is intended to supplement the drawings and summary information provided above and present photos and brief additional descriptions of key process facility equipment. As above, equipment is discussed in the order of flow of biomass through the system. Exhibit 24 shows a photo of the bale infeed conveyor line, including the separate sections for twin bale conveying, the bale merge conveyor, the bale sensing conveyor and its microwave moisture sensor, the bale reject conveyor and its bale reject platform, and the De-Stringer conveyor. All key motor horsepowers for the conveyor line, mills, fans, feeders, and blowers are tabulated in Chapter 5, Exhibit 72and Appendix C.

Exhibit 24 Bale Conveyor Line Photo



Twin Bale Conveyor – As shown in Exhibit 25, Bales were loaded onto the twin bale conveyor with a four bale grapple attached to a teleboom loader. This 'double wide' design provided a shorter conveyor that could hold up to 14 bales. A single line conveyor that could hold this many bales would extend farther than the building length allowed. Allowing 14 bales of capacity only required loading once an hour.

Exhibit 25 Twin Bale Conveyor and Teleboom Loader

Bale Merge Conveyor – Shown in Exhibit 26, the merge conveyor is a 'double-wide' conveyor as well. This conveyor accepts bales from the twin bale conveyor and pivots from side to side to load bales one at a time onto the single-bale portion of the conveyor line. This conveyor's operational sequence is illustrated in Exhibit 26. The conveyor accepts a pair of bales from the twin-bale conveyor and, when the bale sensing conveyor is empty, advances the first bale straight through to the bale sensing conveyor and past the microwave moisture sensor (this step is shown in the upper left photo of Exhibit 26). When the first bale has been fully advanced, the conveyor pivots to a position that lines the second bale up with the single conveying line (shown in the upper right photo of Exhibit 26—note the empty portion of the conveyor extending past the edge of the other conveyors in this photo). When the bale sensing conveyor is empty again, the merge conveyor advances the second bale onto the bale sensing conveyor and past the microwave moisture sensor (this step is shown in the lower left photo of Exhibit 26). When the second bale has been fully advanced, the conveyor is now empty and pivots back to its home position ready to accept a new pair of bales from the twin bale conveyor (shown in the lower right photo of Exhibit 26).

Exhibit 26 Bale Merge Conveyor Photos

Bale Sensing Conveyor – This conveyor is shown in Exhibit 27. As bales are transported across the bale sensing conveyor, a microwave sensor (transmitter and receivers located on opposite sides of the conveyor) measures the moisture content of the bale at each point along the centerline of the bale. The sensor provides an average moisture content reading once the bale has fully advanced onto the conveyor, and sends that information to the biomass processing facility database and also to the OGS data system. Once the bale stops fully on this conveyor, a digital scale using load cells measures the bale weight and transmits that information to the two process databases (OGS, and biomass process facility). After the moisture and weight measurements are taken and transmitted the bale sensing conveyor advances the bale at a speed that makes it flush with the previous bale. This bale crowding was a very important feature of the conveyor and control systems to enable steady bale feeding through the De-Stinger and into the Debaler. Steady flow of crowded bales enabled both of those pieces of equipment to operate optimally.

Exhibit 27 Bale Sensing Conveyor Photo

Bale Reject Conveyor – The bale reject conveyor, shown in Exhibit 28 (prior to integration into the conveyor line), is responsible for removing off-specification bales from the processing line (according to process facility limits and/or fuel supply contract requirements). The control system is automated to remove bales that have moisture limits above a certain threshold. This threshold is set by the control room operator based on either fuel supply contract requirements or optimizing processing equipment operation. The control room operator may also manually remove bales using the control interface. The bale rejector is located just past the bale sensing conveyor on the processing line and resembles a large pitch fork that stabs, lifts, and pushes bales horizontally onto a platform for removal by a track loader or the Teleboom loader.

Exhibit 28 Bale Reject Conveyor Photo

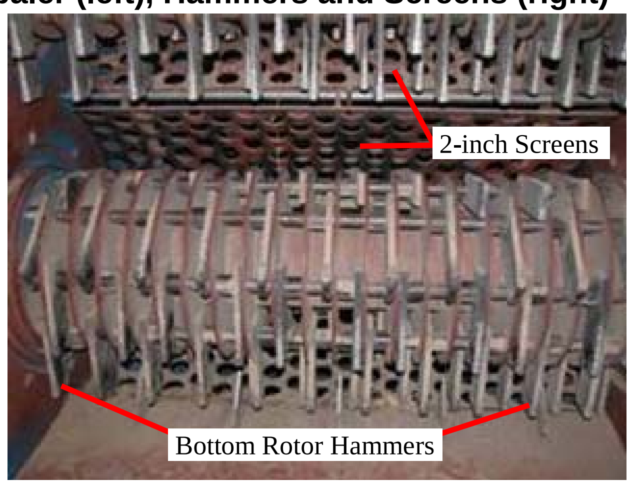
De-Stringer – The De-Stringer from Warren & Baerg (Exhibit 29) removes the twine from the bales. A sled rides on top of the incoming bales and senses the end of the incoming bale when it encounters the dip between adjacent bales. That triggers a signal to start the cutting sequence—there is an adjustable delay that can be set by the control room operator to adjust the positioning of the bale on the conveyor when the twine cutter begins its cycle. A blade cuts the twine from underneath, and a hook/finger removes it from the top of the bale and drops the twine into a disposal/recycling bin (right photo in Exhibit 29). Because the bales have been crowded tightly together by the conveyor line, they don't spring apart when the twine is cut. The cutter on the bottom and the twine removal finger on the top are moved by the same chain. As the cutter cycles forward to cut the twine on the bottom of the bale, the twine removal finger retracts backward across the top of the bale and the finger retracts upward so as not to drag across the bale. Then, as the twine removal finger cycles forward and lowers to remove the twine, the cutter cycles backward across the bottom of the bale.

Exhibit 29 Warren & Baerg De-Stringer Photos

Kelderman Manufacturing developed and installed a roller wheel to automatically sense the height of incoming bales. If the bales were too short for the twine removal finger to be able to pull the twine off the top of the bale, a hydraulic lift under the center of the bale pushes the center of the bale upward high enough so the twine removal finger can capture the twine. After the twine is removed, the lift lowers to its home position.

Debaler – The Debaler (shown in Exhibit 30) is the first of two hammermills in the processing line. As the bale enters, it is chopped from the top and bottom by two horizontal, counter-rotating sets of hammers. Each set of hammers is driven by a 200 hp electric motor (the unit was designed for operation with 250 hp motors). Because the hammers are not fixed (each hammer can pivot individually), this machine is able to process bales containing moderately sized rocks and metal without breaking hammers or causing a shutdown. The debaled switchgrass (and tramp material) must pass through a screen before exiting the Debaler (right photo, Exhibit 30). Through a series of process tests prior to the Long Term Test Burn, the project team determined that two-inch screens offered the best performance when the whole system operation was considered (including impacts on the loading on the second stage mill, the “Eliminator”). Testing was performed using ½”, 1”, 2”, 3”, and 6” screens (results shown in Appendix I). When it was determined that the bottom motor was experiencing the highest loading (through the occurrence of frequent fault messages from the operating system indicating high currents for the lower motor) and was limiting throughput through the processing system, the project team installed a ramp inside the debaler to lift the bale as it entered the milling chamber to provide more even loading between the bottom and top motors. This increased the overall processing capacity of the system.

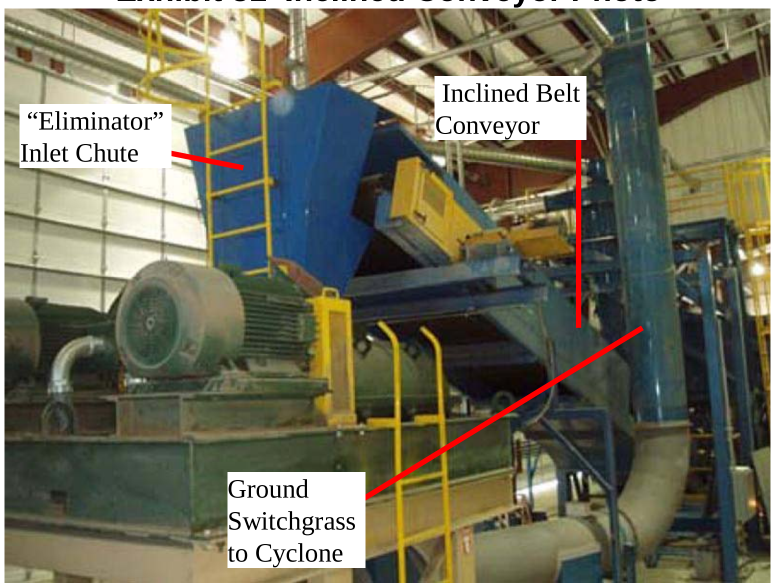
Exhibit 30 400 hp Warren & Baerg Debaler (left), Hammers and Screens (right)



Inclined Conveyor (Debaler to “Eliminator” Conveyor) – As the debaled switchgrass exits through the chamber below the Debaler, an inclined conveyor belt transports the material to the “Eliminator” inlet chute (shown in Exhibit 31). An access hatch and platform were built near the pick-up end of the conveyor to allow flow inspection and material sampling after the Debaler and before the “Eliminator.” The exit chute from the

Debaler and the inlet chute to the "Eliminator" were the two areas most prone to material bridging. The speed of this conveyor was automatically controlled to help avoid bridging problems in the "Eliminator" inlet chute by momentarily reducing the feed rate of material into the "Eliminator" when electric current measurements on the "Eliminator" motors exceeded a limit set by the control room operator for a specified period of time (usually several seconds). When feed rates of this conveyor were reduced, the feed rate of bales into the Debaler was also reduced or stopped to avoid material bridging problems at the pick-up end of the inclined conveyor.

Exhibit 31 Inclined Conveyor Photo



Magnetic Belt – As shown in Exhibit 32, a 6 kW suspended electromagnet with a rotating belt is located across the top of the Inclined Conveyor just downstream from the pick-up end of the belt. The purpose of the magnet is to remove tramp iron from the material on the conveyor belt before it enters the "Eliminator." Because of the rotating belt, the magnet is self-cleaning. As the belt rotates, it carries collected iron to the edge of the conveyor and drops it into a collection bin for periodic manual removal by floor operators. To reduce dust generation, the belt is operated very infrequently (e.g., for one minute each hour). The magnet continues to collect material when the belt is not running. The control room operator can adjust the time between belt cycles, and the duration of each operating period from the control screen.

In comparison to the low-speed debaling operations in Europe where iron and tramp materials are removed before any milling is performed, the operation employed in this system results in passing all tramp materials in the bales through the first stage of the milling process. This resulted in a few stoppages of the system during processing when a large piece of metal (metal fencing, baler parts, etc.) had been baled and entered the Debaler. One outage occurred during the Long Term Test Burn when a long piece of metal fencing entered the Debaler and created sparking that led to a small fire which passed from the Debaler to the Inclined Conveyor and through the “Eliminator.” The fire was detected by the spark detection system in the ductwork downstream of the “Eliminator” and no significant damage occurred.

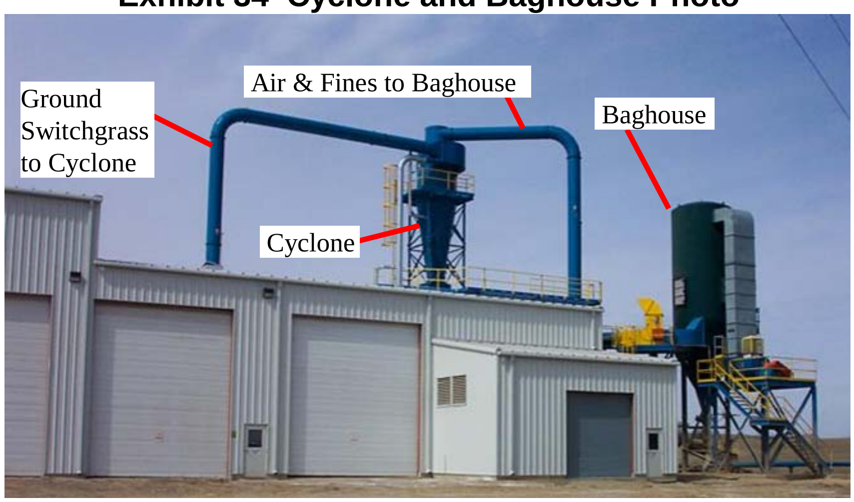
Exhibit 32 Magnetic Belt Photo

The “Eliminator” – The “Eliminator” is the second and final milling stage of the processing system. Shown in Exhibit 33, switchgrass enters the top of the mill through an inlet chute at the rear of the mill casing. Material is reduced in size by two horizontal, high-speed, counter-rotating sets of large, fixed hammers. Each rotor shaft is driven by a 300 hp electric motor. Material is drawn out of the bottom front of the mill casing by suction created by the baghouse fan. Suction through the mill can be varied using a manual damper located at the inlet of a duct under the mill. Opening the damper allows more air to be drawn from the building interior through the duct opening. Closing the damper creates more suction at the mill discharge, forcing more air to be drawn through the mill and reducing the residence time of particles within the mill. This mill is the piece of equipment in the process line with the least amount of excess capacity.

Exhibit 33 "Eliminator" Photos (Rotors and Hammers on right)

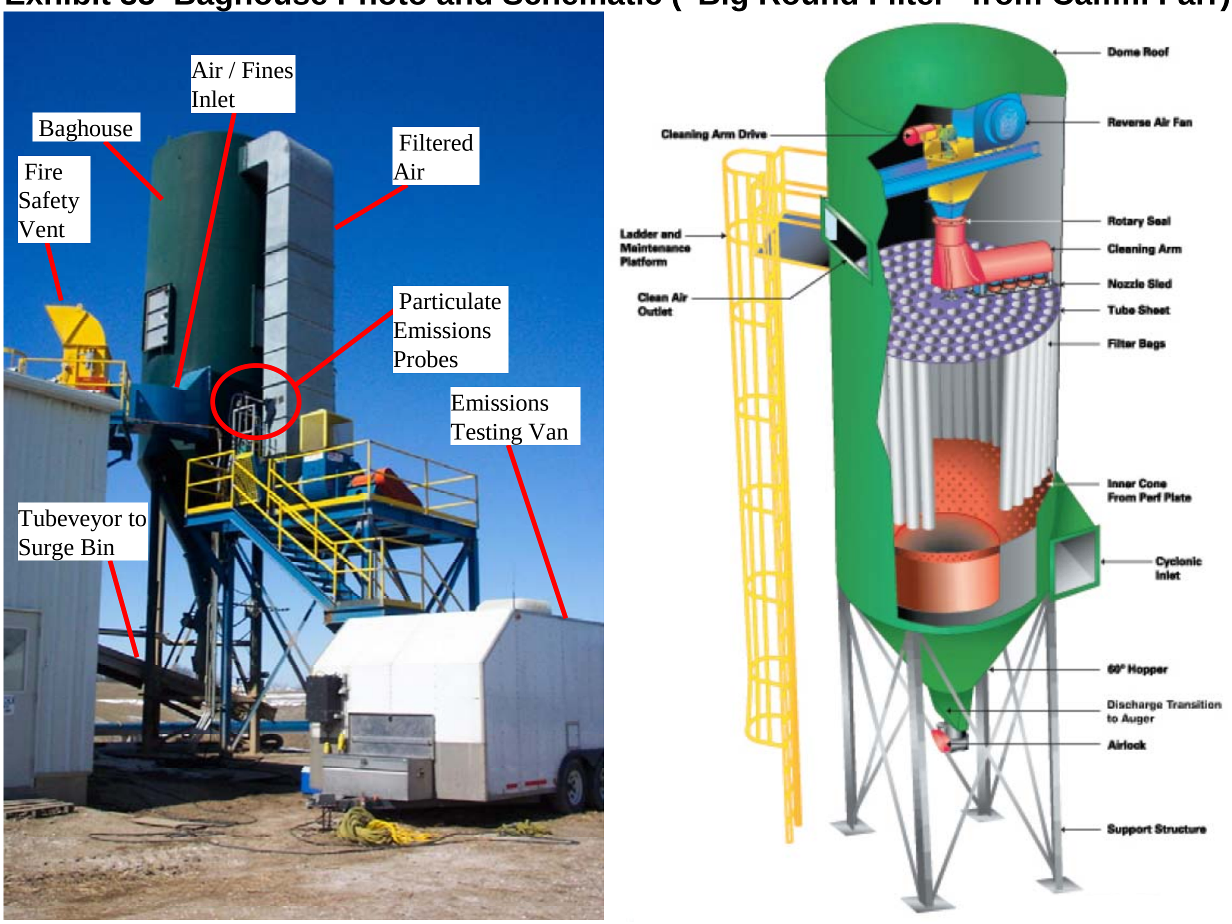
Primary Cyclone – The processed switchgrass from the "Eliminator" is pneumatically transported to the primary cyclone where large particles are separated from the air and fine particles. Exhibit 34 shows the primary cyclone, the piping that delivers ground switchgrass and air from the "Eliminator" discharge to the cyclone, and the piping that carries air and fine particles that were not captured by the cyclone to the baghouse for final filtering. An estimated eighty percent of the solid material entering the primary cyclone is collected and dropped into the surge bin. The estimated maximum air flow though the primary cyclone was about 23,000 cubic feet per minute (cfm).

Exhibit 34 Cyclone and Baghouse Photo



Baghouse – Exhibit 35 shows a photo and internal schematic diagram of the baghouse installed at the biomass processing facility. The filter is actually a combination cyclone and baghouse from Camfil Farr (their model name is "Big Round Filter"). Dust-laden air enters tangentially at the bottom of the filter. Like in the primary cyclone, this creates a cyclonic effect that removes larger particles from the flow and drops them to the bottom of the filter. The air exits the cyclone portion of the filter by moving upwards through a collection of hanging bags. Fine dust collects on the exterior of those bags. A blower located on a rotating arm above the bags rotates around the center of the baghouse, blowing air downward through the bags below it. This knocks the dust on the exterior of the bags into the bottom of the filter with the other collected biomass, periodically cleaning each bag and allowing the material that had been collected on the bag to be removed through the rotary airlock and covered conveyor at the bottom of the baghouse. The collected solids are conveyed back to the surge bin in a covered conveyor so that material can be sent to the OGS boiler along with the solid material that was collected in the primary cyclone. The air that passes through the bags exits through the gray rectangular duct that extends out from the top of the filter. A 23,000 cfm centrifugal blower attached to the baghouse draws air from the "Eliminator" discharge, through the primary cyclone, through this baghouse, and exhausts the filtered air to the atmosphere. The photo shown on the left in Exhibit 35 shows the baghouse during operation while the emissions testing contractor was measuring particulate emissions for air/environmental compliance testing.

Exhibit 35 Baghouse Photo and Schematic ("Big Round Filter" from Camfil Farr)

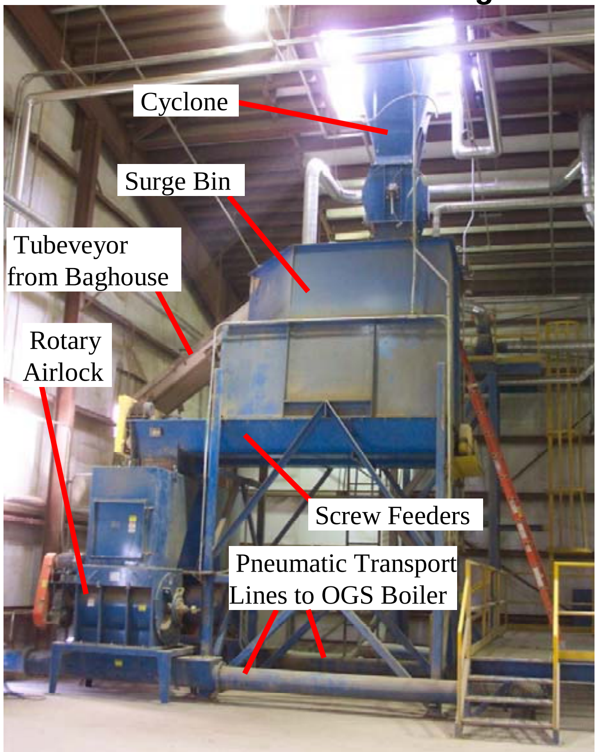


Because of the presence of fabric bags and dust inside the baghouse, this is part of the processing system that is most sensitive to fire and explosion issues. To minimize the risk of fire or explosions in the baghouse, a multi-zone high-speed spark detection system including water sprinkling was installed in the ductwork between the “Eliminator” discharge and the primary cyclone. If sparks are detected in the duct, a damper upstream of the baghouse closes and exhausts the air in the duct to the ambient air.

Baghouse Conveyor (Tubeveyor to Surge Bin) – As the switchgrass exits through the rotary airlock at the bottom of the baghouse, a fully-enclosed belt conveyor (tubeveyor) transports the material back into the processing facility and drops it into the surge. This conveyor is kept at slight negative pressure to minimize the amount of dust that leaks out of the conveyor. The conveyor can be operated continuously, or periodically. If operated periodically, care must be taken by operators to ensure that the baghouse is emptied frequently enough so that collected dust doesn’t build up too much inside the baghouse. The advantage of operating the conveyor and the baghouse rotary airlock periodically is that it minimizes dust generation associated with this conveyor. Exhibit 35 and Exhibit 36 show photos including the head and tail portions of this conveyor, respectively.

Surge Bin – Exhibit 36 shows photos of the surge bin and rotary airlocks which feed processed switchgrass into the pneumatic transport lines from the biomass processing facility to the OGS boiler. As switchgrass is dumped into the surge bin from the primary cyclone located directly above the surge bin, and from the baghouse conveyor, the material is in final processed form and ready to be sent to the OGS boiler for firing. The surge bin is essentially a staging container that holds switchgrass before it enters the pneumatic transport system. Two screw feed conveyors at the bottom of the bin push the switchgrass into the rotary airlocks. The screw feeders are operated at maximum speed at all times to run the surge bin in a starved mode, minimizing the potential for material build-up within the bin.

Exhibit 36 Surge Bin and Rotary Airlock Photos

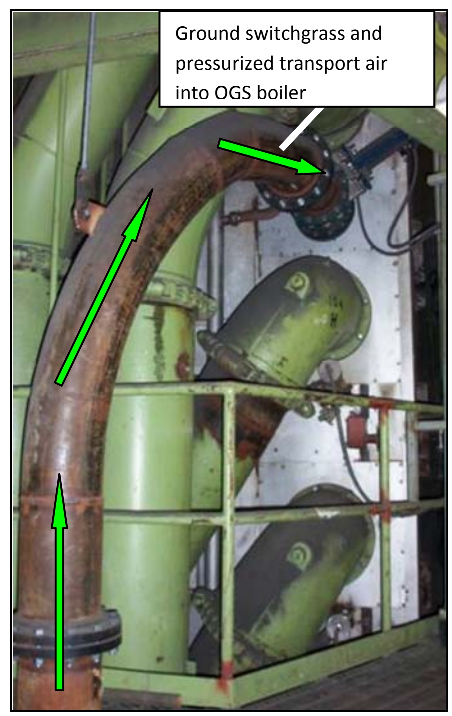


Rotary Airlocks – Two 24-inch diameter rotary airlocks, shown in Exhibit 36, each feed switchgrass from one side of the surge bin into one of the two pressurized pneumatic transport pipes. These airlocks allow feeding of biomass from the unpressurized surge bin into the pressurized transport pipes. Preventing fine particles from leaking through the seals and building up inside the airlocks to the point of causing the airlocks to slow or stop rotation was an important on-going maintenance issue throughout the Long Term Test Burn.

Exhibit 37 Photo of Pneumatic Blowers for Biomass Transport

Pneumatic Transport Blowers & Transport Piping – Two 100 hp positive displacement rotary blowers, shown in Exhibit 37, generate pressurized air flow that conveys the switchgrass through the transport piping to opposing corners of the east furnace fireball. Each blower produces about 3000 cubic feet per minute of air flow at a typical blower discharge pressure of about 4.5 psig. The 10-inch diameter transport piping, shown in Exhibit 38, extends approximately 1,500 feet from the Biomass Processing Facility to the OGS boiler. The support towers (left photo of Exhibit 38) elevate the pneumatic transport pipes 17 feet off the ground across the OGS property and are designed to accommodate two additional transport pipes in case the capacity of the processing facility is doubled to its full design capacity of 25 tons per hour. The right photo in Exhibit 38 shows one of the transport pipes as it feeds the switchgrass burner at the corner of the furnace windbox.

Exhibit 38 Processed Biomass Transport to Boiler



3.3.5 Existing Status of Processing System

Within weeks of the completion of the Long Term Test Burn, the Biomass Processing Facility at OGS was mothballed. No additional operation has occurred since that time. As part of a boiler performance optimization project at OGS, the switchgrass nozzles were removed from the boiler. Nearly all of the pneumatic transport piping leading to the boiler remains in place for possible future re-installation of the switchgrass burners. The automatic fly ash sampler has also been disconnected, but could be re-installed if needed in the future. Prior to restarting the facility, all electrical switchgear, wiring, and equipment will need to be closely inspected to identify potential water damage which may have occurred while the facility has been de-commissioned.

3.3.5.1 Estimated Needs and Costs of Upgrades to Enable Commercial Operation

The processing system in the Biomass Processing Facility was not entirely designed for a commercial operation—some concessions were made to save costs leading up to the test burn recognizing that the system's primary initial requirement was to function well enough to achieve the objectives of the 3-month continuous test burn--the system accomplished those objectives. In addition, based on the operational experience gained during the test burn, a number of important process improvements that should be implemented prior to beginning future commercial operations were identified. After completion of the Long Term Test Burn, T.R. Miles Consulting performed two estimates of requirements to upgrade the facility and process equipment prior to entering commercial operations. Each of those estimates is provided in Appendix D. The estimated upgrade costs ranged from about $600,000 to $1.7 million depending on the amount of redundancy incorporated into the system. The amount of redundancy required would depend upon the importance of reducing / eliminating production shutdowns or periods of reduced processing capacity (due to processing high moisture or poorly packaged bales, alternative materials such as corn stover, etc.) in the fuel supply agreement between the processing facility operator and Alliant Energy / IPL.

3.4 Cost/Value of Facilities

A detailed construction budget tracking table for the process facility construction for the Long Term Test Burn is provided in Appendix D. The facility construction was completed for about $2.5 million during 2005. Some key equipment from the prior test burns was re-used, including the baghouse, the "Eliminator," the Debaler and De-Stringer (with modifications), surge bin, and portions of the conveyor systems and motor control center. The total estimated installed cost of all equipment was about $3.2 million. Applying escalation factors from the purchase/installation date of each portion of the processing facility to obtain an estimated total installed cost in 2008 dollars yields a total estimated construction cost for an identical facility, if built in 2008, of about $3.8

million (or about $4.1 million if costs for construction of the “Biosilo,” the original processing building for the first two test burns, are included in the total). Exhibit 39 through Exhibit 41 provide additional details on cost and general performance parameters for the processing facility. On a cost per kW of biomass power generation capacity basis, the facility cost was about $290 per kW. On a cost per ton per hour of biomass processing capacity, the cost of the facility would be about $410 per tph. Since the facility was designed to accommodate two processing lines, these numbers would be reduced on a $ per kWh and $ per tph basis if the second processing line was installed in the same facility. The numbers would increase if more automated and expanded on-site bale handling and storage equipment was installed, similar to the straw-fired systems in Europe. In addition to the construction and facility upgrade cost information mentioned above, Appendix D also provides additional details on the cost escalation factors that were applied to the original purchase and construction costs to arrive at the estimated 2008 cost estimates provided above and in Exhibit 39 through Exhibit 41.

Exhibit 39 Line Item Biomass Process Facility Costs (in 2008$)

Expense Description	Estimated Cost		Group Code
Additional Biomass Storage Building (the "Biosilo")			
Bio Silo Building	$	184,582	URFC
Site Preparation	$	102,864	URFC
Total Cost of Bio Silo	$	-	
Switchgrass Processing Equipment			
Bag House	$	65,801	PS
Bag House Fan	$	7,194	PS
Meter Bin	$	71,269	RPE
Single Bale Infeed Conveyor	$	64,364	C&I
Twine Remover	$	33,784	RPE
Debaler (Horizontal Hammer Mill)	$	128,392	RPE
Debaler Outfeed Conveyor	$	64,360	C&I
Rotary Airlock/Feeders	$	58,833	PS
Eliminator (Attrition Hammermill)	$	351,894	RPE
Spare Parts (Hammers for Eliminator and Debaler Screens)	$	8,438	SpP
High and Low Pressure Pneumatic System	$	627,268	PS
Bale Merge Conveyor	$	126,869	C&I
Moisture Meter (Microwave)	$	16,792	E&C
Bale Rejector	$	14,060	C&I
Electro Magnet	$	26,136	RPE
Total Processing Equipment Costs (not including installation)			
Processing Facility and Civil, Mechanical, Electrical Installation Costs			
Processing Facility (1)	$	484,386	
Site Environmental Analysis	$	1,708	SP
Site Preparaion	$	163,551	SP
Utilities Site Preparations	$	124,469	SP
Permitting	$	4,480	SP
Fire Protection System and Equipment	$	222,433	FP
Mechanical Installation	$	227,868	MI
Electrical Installation	$	503,675	E&C
Concrete	$	319,490	B&C
Pipe Bridge Foundations	$	40,311	PS
Boiler Modifications	$	-	
Safety and Warning Signage	$	1,403	MO
Total Installation and preparation expenses Items 19 thru 29	$	-	
Total cost of processing facility and installations items 18 thru 29	$	-	
Miscellaneous Other Expenses			
Telephone System	$	4,683	MO
Computers	$	6,749	MO
Furniture	$	5,521	MO
Material bins (3)	$	662	MO
Hand Held Moisture Meter (2)	$	337	MO
Safety Equipment Gas meter	$	1,363	MO
GRAND TOTAL	**$**	**4,065,987**	

Exhibit 40 Summary of Biomass Process Facility Costs by Category (2008$)

Expense Description	Estimated Cost	Group Code
Conveyors and Infeed System	$ 269,652	C&I
Electrical & Controls and Installation	$ 520,467	E&C
Building, Concrete	$ 803,876	B&C
Pneumatic System	$ 799,407	PS
Site Prep	$ 294,208	SP
Fire Protection System & Equipment Installation	$ 222,433	FP
Related Process Equipment	$ 611,475	RPE
Mechanical Installation	$ 227,868	MI
Spare Parts	$ 8,438	SpP
Misc. Other	$ 20,718	MO
Subtotal	**$ 3,778,540**	
Un-related Process Equipment	$ -	URPE
Un-related Facilities Costs	$ 287,447	URFC
GRAND TOTAL	**$ 4,065,987**	

Exhibit 41 Summary of Biomass Facility Performance and Cost Parameters

Biomass Processing Facility Descriptors:		
Building Square Footage:	17,625	ft^2
Installed kW of Load:	1,144	kW
TPH Process Capability:	10.0	tph
Nominal Power Generation Capacity (MW)	14	MW
Installed Cost per kW of Biopower Generation:	$290	/kW
Installed Cost per tph of Biomass Processing Capacity:	$410	/tph

4 Biomass Processing System Operational Experience

4.1 Introduction

4.1.1 Background

The primary objective of the Long Term Test Burn (LTB) was to evaluate the long-term impacts of co-firing switchgrass with coal on the boiler at the Ottumwa Generating Station (OGS). In order to accomplish this, a full scale switchgrass processing system was built to simulate operation 24 hours per day and 7 days per week. The equipment selection and process design was based on previous tests and on a system design for a full scale production of 25 tons per hour (tph).[8,9,10] The processing system built for the test is designed to be the first part of a full scale processing system. The engineering team[11] designed new equipment and components to adapt to the circumstances of switchgrass harvest that are different from other straw systems in cofiring or stand-alone power plants. Due to budget limitations a complete 12.5 tph processing system with all auxiliary systems was not completed. Additional capital equipment must be added if processing is to be performed using this facility on a commercial basis. This chapter describes the design and operation of the system and the recommendations for commercial development and operation. Photos, drawings, and descriptions of individual components in the biomass processing system that was installed for the LTB are provided in Chapter 3, and detailed presentation of data collection and performance results from the test burns is presented in Chapters 6, 7, 8, and 9, and Appendices I, J, K, N, and O.

Design engineering for the project was conducted between the Interim Test Burn in 2003 and initial construction in 2005. Procurement began in the Spring of 2005. Equipment was fabricated and construction began in the Summer. Commissioning started in December 2005 and continued through February 2006. The test burn was conducted between outages in February and May 2006. Full commissioning and further development took place in the first half of the test burn. Full production in a commercial mode was conduct during the last six weeks of operation. Requirements for commercial operations are detailed below.

4.1.2 Operating Objectives for the Long Term Test Burn

The principal operational objectives for the LTB were:

- Production of 25,000 tons at 12.5 tph

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[8] Summary of Chariton Valley Switchgrass Co-Fire Testing at the Ottumwa Generating Station in Chillicothe, Iowa. February 2002.
[9] Chariton Valley Biomass Project – Department of Energy Project Update. December 2004.
[10] Chariton Valley Biomass Project Design Package. July 2002.
[11] Engineering Team coordinated by Bill Morton of Alliant energy included Antares, Inc. Bradford Conrad Crow Engineering, Dong Energy (formerly Elsam Engineering), Kelderman Manufacturing and T.R. Miles Technical Consultants.

- Verify Capacity at 12.5 tph
- Verify Reliability
- Reduced maintenance
- Increase operator safety
- Reduce operator intervention

Each of the operational objectives is briefly discussed below:

Production: The main goal of the LTB was to process 12.5 tph switchgrass for 2000 hours, firing up to 25,000 tons of switchgrass to expose boiler tubes to typical inorganic chemicals and potential erosion and corrosion from co-firing switchgrass. Previous tests had been shorter term in duration for 10 to 12 hours at a time with no continuous production.

Verify Capacity: The design capacity for the full-scale switchgrass processing system is 25 tph in two processing lines or an average of 12.5 tph for each line. Switchgrass test burns in 2000 and 2003 were labor intensive. Short term capacities of 12 to 15 tph were obtained. Testing did not run for 24 hours continuously and the combined quantity of bales used in both tests was about 4,300 bales and about 2,050 tons. An objective of the LTB was to process an average of 12.5 tph for the expected duration of the burn (2000 hours).

Verify Reliability: The reliability or availability of the processing system is the sum of the efficiencies of all the unit operations from bale handling through bale processing, final milling and conveying to the boiler. The objective of the LTB was to obtain a commercial level of reliability throughout the entire processing system.

Reduce Maintenance: Straw processing systems for co-firing in Denmark are characterized by high maintenance in milling operations. An objective of the LTB was to demonstrate methods of debaling and secondary grinding that would reduce overall maintenance and increase reliability.

Increase Safety: Initial co-firing tests in 2000 and 2003 employed unit operations that required operator intervention and were visibly not safe for operators. In 2000 there was initially a high dust hazard. Manual twine removal required continual manual intervention as bales were processed at 2 per minute, a higher rate than in other systems in use around the world. An object of the LTB was to reduce operator exposure and demonstrate safe operations compared with other systems and previous tests.

Reduce Operator Intervention: During short term tests operators were required to intervene to maintain product flow in almost every unit operation. An objective of the LTB was to reduce operator intervention and have as automatic a system as possible.

4.1.3 Design Criteria for Handling and Processing Equipment

Equipment for the LTB was designed to an industrial quality that would withstand 8,000 hours per year of production. Heavy steel was used for conveyors and bins compared with most agricultural equipment which is designed for only a few hundred hours of operation per year and for long maintenance intervals between harvests. The biomass processing line at OGS was designed to operate 24 hours per day and 7 days per week.

Budget constraints led to choices between automation and manual operation for some bale handling operations. A loader with a special attachment for bale handling was used instead of an automated crane system. A second baghouse for process dust collection was not purchased—this baghouse would have filtered the air within general areas of the building, while the baghouse that was installed collected and filtered dust from specific dusty locations within the material processing and handling system. Compressed air was not supplied to the building and other auxiliary systems were deferred until full-time operation. Budget limits also affected redundancy. Since the risk of failure in a three month campaign were assumed to be low, spares or redundant mechanical and electrical functions for critical processes were not installed.

New technologies were demonstrated and tested or applied for the first time in the U.S. during the LTB. A microwave moisture meter not previously used in the U.S. was procured from Denmark. The first bale hook for handling four large bales at a time with a loader was built and used in the test. Since bales were loaded two-wide on an infeed conveyor to gain operator time, an automatic bale "singulator" or merge conveyor was developed to provide a single stream of bales to the debaler. A unique twine remover that was developed for the project during the Interim Test Burn in 2003 was modified for full-scale production. A bale ejector that would reject over-wet or non-spec bales was developed and tested. Bale limit switches and bale conveyors were based as much as possible on experience learned in Denmark, the UK, and on the U.S. experience with handling straw—operation of these devices were improved during the test.

Systems developed and demonstrated in the 2000 and 2003 test burns were improved and incorporated into production. The horizontal hammermill-debaler tested in 2003 was used to debale and preliminarily size straw prior to secondary grinding. The secondary grinder (the "Eliminator") which had been used for the first time at high rate processing of switchgrass in 2000 was reused in 2003 and incorporated into the production line as the primary secondary grinder for the LTB.

4.1.4 Long Term Burn and Commercial Operation

The LTB was intended to simulate commercial production as much as possible. Mechanical processes and system controls were developed which could be expanded and adapted for full-scale production. Controls and communications were linked to the OGS plant control system to integrate operations and data with the plant. Safeguards were incorporated into the controls so that OGS could interrupt fuel flow if necessary, either in a manually triggered system shutdown or one automatically triggered by the OGS control system. Much of this had been developed during the Interim Test Burn in 2003, but was improved significantly prior to the LTB.

4.1.5 Commissioning and Startup

Mechanical, electrical, building services components and controls were each commissioned during installation. Vendor supplied equipment was started up by individual vendors when it was possible. Equipment ahead of the debaler was commissioned with straw bales prior to full operation. Equipment past the debaler was commissioned without material until authorization was obtained February 15, 2006 to fire straw in the boiler.

Equipment that was reused from previous tests was reconditioned or modified. The bale infeed conveyor was changed from one bale line to a double bale line with two bales side-by-side. The twine remover was modified to be adjustable to bale height. The debaler was raised to allow better straw discharge. The infeed to the debaler was raised to more evenly distribute the infeed materials to the debaler rotors.

Original equipment designs included some bale conveyors, the bale singulator to merge two lines of bales into one, the weighing conveyor that included the microwave moisture detector and load cells, and the ejector which incorporated hydraulic forks to eject unwanted bales.

Improvement of controls and operation of each individual process was ongoing throughout the LTB and evolved as a function of the quality of straw processed which was only possible while running straw in full production. For example as bale quality deteriorated the friction on chains changed and bales lost traction. This led to changes such as increasing the height of the bale off the deck and adding bale position sensors. Variation of bale quality lengthened commissioning of mechanical systems and controls. Commissioning was extended due to the variability of bale packages and bale quality as discussed below. Commissioning took up the first 500 hours of production or about 6 weeks before smooth production was possible on a nearly continuous basis. This is a fairly typical commissioning window.

4.2 Fuel Quality and Production

4.2.1 Background

Uniform supply of switchgrass is essential to full-scale co-firing in the OGS boiler. Since the fuel must burn in suspension it must burn completely in the coal burning environment and leave a minimum of ash or unburned fuel in the bottom ash and fly ash. Based on results in previous test burns, moisture and particle size are the most important factors for obtaining good biomass burn-out and steady combustion performance in the boiler. Co-firing tests in 2000 and 2003 had achieved sufficient size reduction and uniform moisture to permit continued testing, so particle size of fuels fired in 2003 became the standard for the LTB.[12] The primary basis for determining if proper fuel sizing had been achieved in previous test burns was whether an acceptably low amount of unburned carbon was found in bottom ash and fly ash, and whether acceptable particulate and carbon monoxide emissions had been achieved with a particular fuel sizing during tests. The optimal balance between reliable continuous process operation, minimized processing power consumption, and acceptable fuel sizing was achieved with 2-inch screens in the debaler, with secondary grinding in the attrition mill (the "Eliminator"). A report discussing the testing performed to arrive at that conclusion is provided in Appendix K.

4.2.2 Fuel Quality

Fuel quality was monitored according to a fuel processing agreement between IPL and Chariton Valley RC&D for the LTB.[13] That fuel processing agreement was based largely on a Commercial Fuel Supply Agreement executed between Prairie Lands BioProducts, LLC (Seller) and Interstate Power and Light Company (Buyer). Fuel specifications covered quality, conditions for bale rejection, weight, moisture content, and sampling and analysis requirements. Due to the experimental nature of the demonstration, fuel quality was measured and observed during the initial phases of the test burn and actively managed for peak production during the latter phases of the test burn. It became apparent that better fuel quality than that specified in the contract was necessary to guarantee high production rates and minimize processing equipment outages.

Initial specifications required that the delivered biomass fuel:

- shall be substantially free of foreign material.
- shall not contain any foreign bodies and no ammonia or other chemicals shall be added after the bales have been pressed.
- shall conform to the following specifications as-received.

[12] Antares Group, Interim Test Burn Particle Size Report, 2004 (Appendix I).
[13] *Test Burn Processing Agreement* between Interstate Power and Light Company (a wholly-owned subsidiary of Alliant Energy Corporation) and Chariton Valley RC&D, Inc. (Appendix Q).

Exhibit 42 Delivered Biomass Quality Specifications: Proximate Analysis

	Contract Typical	Contract Rejection	Units
As Received			
Moisture Content	13.0	> 20.0%	% By Weight
Higher Heating Value	6,892	< 6,338	Btu/lb.

Exhibit 43 Delivered Biomass Quality Specifications: Ultimate Analysis

	Contract Typical	Contract Rejection	Units
Delivered			
Ash	5.4	> 7.5%	% By Weight
Carbon	45.3	--	% By Weight
Hydrogen	4.74	--	% By Weight
Nitrogen	0.53	> 0.80	% By Weight
Chlorine	0.13	--	% By Weight
Sulfur	0.11	> 0.20	% By Weight
Max. Particle Size	0.50	> 0.75	Inches

4.2.2.1 Moisture Content

The target moisture content (MC) for the delivered switchgrass was 13% with rejection over 20% MC. This was based on the experience burning over 2,000 combined tons during the 2000 and 2003 burns that averaged 12% to 14%.[14] Dry bales that had been stored inside for the Interim Test Burn averaged 13% MC, with an overall range of 10% to 22% MC.

Bale moisture was more highly variable for the more than 15,000 tons of switchgrass processed during the LTB; however the overall average moisture content was the same as in the Interim Test Burn. For the Long Term Test Burn, measured average bale moisture contents ranged from less than 10% to as high as 44%, with the overall average for the entire test being 13%. Daily average moisture contents were in a much tighter band, ranging from 10.5% to 15.7%. Bales stored on the ground in the Biosilo, the Straw Palace, the Hoop Building, or in remote storage buildings tended to have higher moisture at the bottom of the bales.

[14] T.R. Miles, Technical Consultants, Inc., Switchgrass Cofiring at Ottumwa Generating Station Summary, December 15, 2003.

4.2.2.1.1 Measuring Moisture Content

Moisture content was measured during the LTB using two methods: a hand probe (Delmhorst FX2000) and a continuous microwave sensor (DEK). Sample bales from each truck arriving at the biosilo were weighed on a platform scale and measured for moisture using a hand probe. Over-wet bales were detected and placed in temporary storage according to moisture content. Bale condition was re-examined by hand probe before either placing the bales into processing or rejecting them.

Moisture was continuously and automatically measured with a microwave moisture detector as individual bales advanced on the debaler infeed conveyors. The microwave gave a continuous scan of the center of the bale over the length of the eight foot bale. Average moisture was displayed to the control room operator and recorded in a database. Initially, over-wet bales were automatically rejected onto a platform where they were retrieved by the loader operator. Rejected bales were then hand probed to detect the source of moisture. Each time the bale rejection mechanism cycled, a signal was recorded in a database both at the biomass processing facility and in the OGS data acquisition system—this allowed Alliant Energy / IPL staff to independently review biomass system operational data and verify that when wet bales (above contract moisture specifications) were sensed, those bales were subsequently removed from the processing system. Rejection based on the microwave data became problematic during commissioning and was abandoned until other processes were fixed. During production it was discovered that a more effective method for handling bale moisture was to hand probe and presort bale packages (of 4 bales each). Production increased and moisture became less of a problem as fuel quality was organized in the barn before biomass was delivered to the processing facility.

Moisture was recognized as the single most important determinant of bale quality that affected production. The microwave detector became useful for operators to control processing. Bales that were clean and dry <14% MC in good clean packages were easily handled on conveyors and in processing through the destringer, debaler and eliminator. Bales that were >14% MC significantly slowed processing in the single line system and were avoided during the latter weeks of the test burn in an effort to maximize daily production rates and minimize process down-time for clearing plugs in process equipment.

4.2.2.2 Bale Composition

Switchgrass bale composition was inspected during bale loading, unloading and processing. In general, the bales contained switchgrass with very little foreign matter. There was a wider variation in bale composition and quality during the LTB than in previous tests. Bales from only one contractor had been used in previous tests, and those bales had been prepared with high quality packages. During the LTB, bales were supplied from several contractors and there was a wider variation in bale content and bale package quality.

Foreign materials varied. While occasional metal parts stopped production, there were very few large pieces. Materials that had the greatest impact on production were the fine grasses (e.g., foxtail) and woody weeds that grow in or alongside the switchgrass. These were easily identified by the loader operators. When bales with foreign species were detected they were inspected before including them in production. Higher moisture content bales and bales containing large quantities of fine grasses such as foxtail slowed production when they hit the debaler. Suppliers recognized the impact of bale quality and the importance of processing primarily switchgrass on production rates at the processing facility. Variations in bale composition had little observed impact on fuel quality from a combustion perspective. They had a much greater impact on the smoothness of the production operation. Although bale content and moisture variability could be controlled to an extent during potential future operations, the processing system should also be designed to compensate for expected variations by increasing processing capacity. Hence, two 12 tph debaling lines would be necessary to guarantee production of 12.5 tph under all conditions.

The occurrence of weeds and foreign materials in the switchgrass depended on the baler contractor, and the general condition of the field where the material was harvested (some fields had more non-switchgrass content than others). Some contractors were noted for larger variation in bale quality which impacted production. Some of the fields contained patches where non-switchgrass species were more prevalent—some of the baling contractors mowed and baled material from those patches while others avoided them when mowing and baling. It was recognized that quality control must start in the field by the contractor, and this could be a factor that quality management and contractor education by the fuel supply organization could help improve commercial production operations.

4.2.2.3 Weights, Sampling, Analysis

4.2.2.3.1 Weight

Bales were received in the processing facility either from onsite or offsite storage. As bales were unloaded from the truck, a sample of three bales from each load was weighed on a platform scale to determine average weight and moisture. Bales were then stacked or staged until they could be loaded onto the processing line conveyor. As the bales were put into a single line, they were loaded onto a weighing conveyor. When the bale hit a limit switch on the conveyor the bale weight was recorded and added to the process database. This total was then compared with the amount of straw received in truckloads. After weighing the bale advanced, twine was removed automatically, and it was debaled and milled before burning. The bale weights were used to measure the amount of biomass fuel that was processed and delivered to the generating station. Combined with moisture content data and heat content data from laboratory tests of switchgrass samples, this weight data was used in monthly fuel supply invoices (Appendix S) and monthly switchgrass fuel use reports prepared for submission to environmental agencies (Appendix H).

Bale weight averaged 990 pounds with a typical range from about 800 lbs to 1200 lbs during the Long Term Test Burn. Bale weight and the consistency of bale weight became another value that operators used to judge the behavior of the bale in processing. Some contractors delivered straw with very consistent weights and densities which were easy to process. Some heavy bales were high moisture bales. Light bales were often simply low density bales that were poorly packaged and had a higher tendency to cause problems on the conveyor system.

4.2.2.3.2 Sampling and Analysis

During the Long Term Test Burn, switchgrass was sampled during periods when performance or deposit testing were conducted. Samples were analyzed in accordance with the applicable standards of the American Society of Testing Materials (ASTM) or equivalent. These tests included: (1) Moisture Content; (2) Total Ash; (3) Higher Heating Value; (4) Total Carbon; (5) Total Sulfur; and (6) Particle Distribution. "Full Proximate Analysis" (performed on an as-received basis) included determination of carbon, hydrogen, sulfur, nitrogen, chlorine, and ash.

The results from this sampling and analysis were compared with fuel laboratory analysis data from the Interim Test Burn of 2003. Laboratory analysis test specifications and results from both the Interim and Long Term Test Burns are available in Appendix K of this report. Switchgrass properties were very similar between the Interim Test Burn and the Long Term Test Burn.

4.2.2.4 Bale Size, Shape, and Density

Bale size, shape and density also varied with the contractor. Each contractor had a different baler or bale configuration. About half of the switchgrass was baled with mechanical balers and half with a hydraulic baler. The widest variation in bale quality came from mechanical balers that were not operated by skilled operators. Mechanical balers with good operators and the hydraulic baler produced uniform bales that had good density and composition. Two contractors had consistently denser bales than the others.

Automatic handling requires stackable packages. Oversized and poorly shaped bales are not stackable packages. Oversized bales were usually over height so the twine remover had to be modified to accommodate a wide variation in bale height. Typical bales were 38 inches tall. Bales were as small as 24 inches tall. Many circumstances can cause poorly shaped bales. Some contractors consistently provided poorly shaped or "banana" bales that could not be handled automatically. These bales suggested that a tub grinder could be used to process loose cleanup material and odd shaped bales during a commercial operation setting. Dust control would have to be a significant consideration associated with the operation of a tub grinder.

4.3 Operation of the Processing System and Equipment

4.3.1 Production Organization

4.3.1.1 Management

Management of overall operation including supply and production was coordinated by Bill Belden, CVRCD, in collaboration with the project's engineering team, Prairielands Bioproducts, and Kelderman Manufacturing.

4.3.1.2 Supervisors

Supervisors teamed in 12 hour shifts rotating through a monthly production schedule. Supervisors were provided by Kelderman Manufacturing. The four shift supervisors were part of the construction team and learned the operation of the equipment on the job. They were also skilled mechanics who solved mechanical problems as they occurred during commissioning and operation. Supervisors provided mechanical solutions for all aspects of production, both in the biomass processing facility and occasionally in the OGS boiler house to repair holes in the biomass supply pipes or flexible couplings/elbows. Additional mechanical support was provided by Kelderman Manufacturing as necessary.

Engineering support was provided for the supervisors 24/7 by the engineering team. Antares and T.R. Miles Consulting coordinated solutions to processing challenges and obtained further support as needed from electrical and controls contractors and other members of the engineering team. They also monitored and evaluated production suggesting mechanical changes, improved operating procedures, or controls improvements. Feedback, suggestions, and mechanical improvements implemented by the shift supervisors was critical to improving system operation and reliability throughout the test burn. During the last month of the test, the processing system operated with very high reliability and low down-time. During the last two weeks of operation, the system was on-line and processing over 95% of the time.

4.3.1.3 Operators

Operators were hired and trained by Prairie Lands with coordination by Chariton Valley RC&D project manager, Bill Belden. It was initially thought that part-time or short-term operators would be difficult to find. Several operators were found with the help of Prairie Lands and some were members of Prairie Lands. Operators were from the local community and often had other jobs. They had varied industrial experience. Some were retired engineers from the John Deere manufacturing facility in nearby Ottumwa.

Two operators manned the production floor at all times. One operated the bale loader and the other tended to the processing line. The second operator spent time with cleanup which would be mostly automated in commercial operations. For most circumstances a supervisor and one operator could process the 12.5 tph switchgrass line, and that could be a potential night shift staffing arrangement if the project moves into commercial operation.

Operators were responsible for unloading and managing the switchgrass as it was received at the facility, recording and weighing bales, testing bales for quality and moisture content, loading the bales onto the processing line, keeping the processing line clean and safe, and ensuring smooth movement of straw through the process. Operators also provided regular maintenance such as lubrication and inspection of equipment.

Operators were given basic safety training during orientation. Operator training could have been more complete especially for operating mobile equipment and on more detailed safety procedures. Handling and processing straw can be hazardous work and no amount of training is enough.

4.3.1.4 Support, Repair, and Maintenance

Twenty-four hour per day support was essential to sustaining continuous operations. When a problem was recognized by supervisors that could not be easily solved onsite, solutions were developed in collaboration with CVRCD and the engineering team and executed by Kelderman personnel or other contractors.

Since the LTB was intended to be a commercial scale demonstration and not a production facility, a full equipment shop with a maintenance crew was not established. Kelderman Manufacturing provided personnel and support for maintenance. This included additional operators, welders and mechanics as needed.

4.3.2 Production Scheduling and Operations

4.3.2.1 Production Scheduling

Production was planned for 24 hours per day during the Long Term Burn. Alternative production schedules were considered and compared with the capabilities of the supervisors and operators. A five shift schedule was developed that was typical of operating plants of this kind but it was not suited to the nature of the test and the needs of the personnel. The four supervisors chose to take 12 hour shifts that rotated between day and night. The operators preferred eight hour shifts which overlapped with the supervisors. This arrangement proved satisfactory.

Switchgrass supply was organized for daytime delivery and provided accumulation of sufficient good quality inventory to minimize supply problems during the night shifts.

Spares and repair parts were ordered in anticipation of using outages for maintenance. There were no scheduled stoppages for maintenance. An attempt was made to perform maintenance activities during unscheduled stoppages. This was not always successful since all the attention and manpower was usually devoted to solving a particular problem. It was more satisfactory to stop production for a maintenance period.

4.3.2.2 Operating Procedures and Training

General operating procedures were outlined in the project plan and reference information was provided for each of the processes. A detailed procedure for startup and shut down was developed with OGS before the LTB. Some of the individual processes were reviewed during commissioning. Since this was a new process detailed procedures had to be developed for many processes. More detailed operating procedures would have aided operators, including an organized help system and maintenance and repair books. While information was often on hand it was not obvious to supervisors and operators.

Training was provided to operators with safety procedures at orientation. More extensive training should be provided for full scale production. Training should include detailed training for specific tasks, such as the operation of the loaders and handling equipment and safety. Not all the operators had much experience with industrial operations.

Control strategy and software for the system was developed specifically for the LTB. It did not include development of support and training documentation. Training for system controls was on-going for the supervisors since controls were changed and evolved during the LTB to solve problems. A flow diagram with sensor types and locations, a list of controlled equipment, and some examples of control screen images are included in Appendix C.

4.3.2.3 Coordination with Ottumwa Generating Station (OGS)

Coordination with OGS was continuous through the engineering team representatives, shift supervisors, and Chariton Valley RC&D project management. A direct control link was provided through the operating system through hard wired and data systems.[15] A procedure was established for startup, shutdown and emergency operation. Operating data from the switchgrass processing was automatically transmitted to the OGS data acquisition system and was available to OGS personnel. The shift supervisor and operators at OGS had the ability to interrupt the switchgrass fuel using a control panel provided in the OGS control room.

Telephone communication with OGS was very effective. It was especially useful when there was a fire in the debaler. Familiarity with local fire personnel and procedures made containment and control easier. Control communications were supplemented by direct phone calls between the Biomass Processing Facility and OGS control room whenever there was an intended change in production or when operators at either site noted possible problems. Biomass Processing Facility supervisors physically inspected the switchgrass delivery lines at OGS daily.

[15] Post 9/11 security precluded a high speed network link from an external facility to the plant network during operations; however, the cable was installed and tested and that link could be easily established in the future if desirable for commercial operations.

Daily informal visits by OGS personnel also contributed to smooth operation between the plants and production.

4.3.2.4 Safety

Processing straw can be hazardous and no amount of training is sufficient. Prior to facility commissioning, the OGS safety officer performed a walk-through of the biomass processing facility and offered suggestions for improving safety measures throughout the facility and operations. CVRCD adopted Alliant Energy safety guidelines for operation with few exceptions. Operators were trained with basic safety procedures during orientation at hiring and signed to confirm that they understood safety requirements. Personal safety equipment including hard hat, glasses, and ear protection were provided by CVRCD. Supplemental dust masks were also provided. Confined space procedures were followed. CVRCD obtained a combustible and toxic gas detector which was used for confined space entry (such as climbing inside the debaler to do repairs, clear plugged material, and change screens). Several production workers were unable to continue working during the commissioning phase due to problems associated with dust. Improvements in the dust removal along the processing line throughout the commissioning process greatly reduced the dust problem; however, if commercial operations were to begin, a separate dust control system designed specifically for cleaning the air in the processing facility would be highly recommended. Due to budget constraints, the only dust control systems installed were directly focused on filtering dust from specific operations within the process where dust was generated in large amounts, or for vacuum cleanup operations.

4.3.3 Production Capacity

Production capacity can be described in terms of system design capacity, operational test capacity, and actual production. Design capacity was 12.5 tph switchgrass at 14% to 16% MC to meet the objectives of the LTB. The processing system design was based on observed and confirmed rates during the test burns in 2000 and 2003. During those tests and during the LTB test, debaling and processing was performed at sustained rates or operational test capacities up to 15 tph on a fairly regular basis. The maximum sustained production rate during the Long Term Test Burn was about 20 tph. In order to avoid material plugging or other operational problems, operators typically set the target system feed rate near the system design capacity—operators would adjust the target feed rate depending upon the nature (moisture, weight, bale content, bale packaging) of the bales on the conveyor line at any given time.

The actual production of the system was measured in tons per day, or tons per month, and results in a net capacity factor, or percent of capacity that is used. Production was summarized by CVRCD project management and Antares daily and distributed to the engineering team, Alliant Energy staff and IPL plant staff, and other interested parties.

The daily production reports included a record of outages and reasons for outages. The results of those reports are presented in Appendix F and Appendix G.[16]

Typical daily production during the latter period of the LTB was 240 tpd for an average of 10 tph or a capacity factor of 80% compared to design capacity. This production rate is twice that of typical straw processing lines employed in Europe. Many factors contributed to the capacity factor. The most significant factors were the availability of switchgrass to the infeed of the debaler and the outfeed of the debaler to the eliminator, where material plugging was most prone to occur. In order to minimize costly downtime for clearing system plugs, the automated control system was programmed to sense conditions which typically preceded material plugs/bridging or other known conditions that would lead to system shutdowns. In response to these measured conditions, the control system would automatically stop or reduce bale conveyor infeed and/or inclined conveyor infeed rates until the problem sensed in the system disappeared. The control room operator/shift supervisor would receive warning messages on the control screen that indicated what the fault was, and when it was cleared. Typical fault messages included high current readings on debaler or eliminator motors, or positive indications from plugged flow sensors at various locations throughout the system that were prone to plugging. Some of the system test measurements and results that led to this control scheme are provided as examples in Appendix I from a series of processing tests performed in August 2004. During those tests, the engineering team determined that high current readings could be measured on debaler and eliminator motors between 5 and 10 seconds before a system plug would become visually apparent to operators. By programming the control system to automatically and quickly reduce or stop material infeed to the piece of process equipment experiencing a high current condition, and waiting for the high current condition to dissipate before gradually ramping production feed rates back up to the operator's system feed rate set point, the system became much more reliable and easier for operators to manage and control, and system downtime for clearing plugged material was greatly reduced.

4.3.3.1 Stoppage

Stoppage most frequently occurred at the twine remover or due to overcapacity at the eliminator. During an initial commissioning period of 500 hours the quality of switchgrass was frequently a cause for outages. After that period, during the last six weeks of production operation was typical of commercial production.

Moisture content and quality of switchgrass were the principal causes of problems at the conveyors, debaler, and eliminator. Potential improvements to reduce stoppages include switchgrass quality assurance, moisture control during baling and storage, and redundancy at the infeed conveyor. The LTB demonstrated that the practical commercial production rate for the debaler is about 10 tph. For reliable operation at higher rates, two debalers would be necessary.

[16] Recipients at OGS, Alliant, EPRI and others commented that these daily reports provided a clear picture of production and convinced them that the LTB was operating as if it was a full-scale industrial activity.

Mechanical wear, damage to sensors, and other problems were secondary causes for stoppages. Many of these could be anticipated with a normal preventive maintenance program. Since the LTB was a limited test a limited amount of spare parts were maintained onsite.

4.3.4 Process Optimization for Full Scale Production

The switchgrass processing system for the LTB was for simulation of a full-scale production, but for a limited period. Critical components of process optimization include:

- Production management
- Switchgrass quality
- Personnel training
- Equipment spares, maintenance and repair
- Controls and data acquisition
- Communication

The LTB has provided valuable experience for each of these aspects of production. Careful planning is recommended for future commercial production to minimize stoppages, maximize production, and ensure operator safety.

4.4 Switchgrass Processing Unit Operations

Burning 15,000+ tons during nearly 1700 hours of operation provided useful experience with unit operations for switchgrass processing. Switchgrass as received provided some different challenges than experienced elsewhere. Equipment and operations were designed based on the experience in England and Denmark by Dong Energy and others where handling systems process a single bale package size.[17] Specific experiences and recommendations should be considered and corrected before entering into full-scale commercial production.

4.4.1 Switchgrass Receiving and Handling

4.4.1.1 Bale Loading and Handling

The bale loading system was designed to be able to place at least two bales at a time on the infeed conveyor so that the loader operator had time to keep up with the process rate of 12.5 tph. A special attachment was built to be able to lift four of the 3 x 4 x 8 ft bales at a time, permitting the operator to place four bales at once on the conveyor.[18] This meant that a single placement would represent about 10 minutes of operating time. The attachment was mounted to a loader with a telescoping boom so that bales could be retrieved from high stacks. The strategy was successful. Operators quickly learned

[17] European straw systems use bales prepared with a Hesston (Agco) baler while different balers making different packages were used in the Chariton Valley Biomass Project.
[18] Bale loader from Steffen Systems, Salem, Oregon, www.steffensystems.com.

how to use the loader. It did create safety hazards when used by operators who were less skilled. Some were more skilled than others.

The infeed conveyor had a storage capacity of 16 bales or approximately 30 minutes of operation. The loader and the conveyor provided enough time for the loader operator to maintain the 12.5 tph production rate with average 1000 lb bales. Capacity was reduced when light bales were being processed (600—800 lbs) and more individual bales had to be handled to maintain production. Production capacity will be increased as average bale weight increases.[19] Handling bales in packages of four gave loader operators enough time to sort incoming bales for quality and condition.

Operators concluded that a single loader could keep up with an operating capacity of 25 tph if necessary. This may be an interim step for 25 tph commercial operations until an automated bale handling system can be built. For full production the automated crane handling system contemplated in the complete system design should be reevaluated.[20] During system design, alternative bale handle systems were considered. These included large and small crane systems, bale squeeze bulk unloading, and several other possible options. Recent discussion with US crane suppliers show that a lower cost crane option could be developed and should be considered if commercial operations are pursued.

4.4.1.2 Bale Conveyors

The bale receiving conveyor is a dual-bale infeed with two 1000 lb bales loaded side by side. The infeed conveyor used for the Interim Test Burn was widened and chains and a drive were added for the additional size and weight. The decision to make this a dual conveyor was based on loading bales two at a time and later putting them into a single line for processing. It is similar to the dual-bale handling cranes that have been in use in Denmark since the 1990s.[21] This arrangement made it possible for the loader operator to load the conveyor with up to 16 bales or 8 tons of switchgrass at a time. It provided enough surge capacity so that the loader operator could unload other trucks, stack and sort bales or tend to the operation of the processing system as intended.

The bale receiving conveyors, bale transfer conveyors, weigh scale conveyor, and bale rejector conveyor were based on the design of the conveyors used in Denmark. The chain spacing and height were all similar. Horizontal runs did not have attachments. The only difference was that heavy duty mill chain was used compared with lighter chain used in Danish designs and U.S. agricultural equipment. Mill chain is designed for year-round operation under heavy conditions. The chains performed well during the Interim Test Burn in 2003.

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[19] During 2006 hydraulic balers were field demonstrated by Allied-Freemen Manufacturing that can produce 1500 lb bales from straw. This would reduce the number of bales required to supply 12.5 tph or increase the capacity for bale handling.
[20] Chariton Valley Biomass Project Design Package. for the US Department of Energy. June 2002.
[21] T.R. Miles. Denmark Trip Report 2002, 2004.

Two problems were experienced with the chain design. Handling bales side by side was not successful with wet or deformed ("banana") bales. Attachments were added to all chains to control bale movement. During early stages of the LTB, significant time was devoted to designing, installing, and testing attachments that would provide adequate bale friction without shredding the bales when they were over-run to crowd bales together for processing. To obtain uniform straw flow, it is necessary to crowd the bales together prior to feeding them into the twine remover and debaler infeed.

Poor quality bales dragged straw on the deck of the conveyors. The friction of the straw on the metal deck stopped the bales. The conveyors must be modified by raising the height of the top of the chains to prevent drag.

Operation during the LTB has shown that two debaling lines are needed to ensure a production capacity of 12.5 tph. Reducing the number of conveyors would reduce the loss of straw during conveyor transfers. Two infeed lines provide the opportunity to reduce the number of conveyor transfers and reduce wastage. At each conveyor transfer, straw and fines are lost through the gaps between the feeding and receiving conveyors. This waste must be discarded or reused in the process--this is a problem for all straw processing plants, even in Denmark.[22]

4.4.1.3 Bale Detection

Mechanical bale limit switches were incorporated in bale conveyor design to determine the location of bales on the conveyor. The limit switches were generally based on designs used in Denmark and were expected to be more reliable than photo-eyes. The wide variation in bale packages caused problems with several switch designs. Significant development occurred until a mechanical bale switch was found that could be used with electronic controls.

Photo-eyes were used successfully to indicate position of the bales on the infeed conveyor. It was anticipated that the eyes would become covered with dust but they were easy to maintain and more could be used to verify bale position.

4.4.1.4 Wet and Broken Bales

Two systems were considered for handling wet or broken bales in processing: an overhead crane, and a bale rejector that would set rejected bales aside for handling by a loader. The bale rejector was constructed for the LTB. There was room on the rejector platform for two rejected bales before the bale infeed line would stop.

In practice, the detection of wet bales using the moisture sensor and setting them aside automatically with the bale rejector became problematic for operation and controls. The first problem was what to do with a large quantity of potentially wet bales. The bales had been accepted by CVRCD over a period of years and could not be returned to the

[22] Additional equipment for straw cleanup is anticipated for commercial operation but was not installed for the LTB due to budget limitations.

supplier. They had to be processed or managed in some form. Bales could become deformed if twine holding the bales broke in conveyor transfers. Operators found that it was easier to process marginal bales and remove wet or deformed bales with the bale handler directly from the process line so the automatic rejector was turned off. The bale rejector could be removed from the bale processing line.

4.4.2 Bale Weight and Moisture Detection

In the automated system in use in Denmark, bales are removed from the trucks with a bridge crane. The crane has weighing devices called load cells that weigh the bales while microwave moisture detectors determine the moisture of each pair of bales. Data from the unloading operation is recorded in the plant database. When those bales are retrieved from inventory this data is used to monitor production. In some plants, additional moisture detectors at the infeed to boilers are used to verify moisture content of the bales. An automated bale unloading system was not used for the LTB due to budget limitations. A truck scale for obtaining the bulk weight of bales was considered but not used for the LTB also because of budget limitations.

A conveyor section was built that incorporated both the weight of the bale using load cells and the moisture detection system. As bales were transferred onto the weighing conveyor, the moisture from the center of the bale was monitored by the moisture meter. When the bale arrived at a limit switch the load cells measured the weight which was recorded to a database in the biomass facility control room. If the bale was not rejected based on moisture content, the bale weight was added to the total weight of switchgrass received by OGS. That weight data, along with the moisture data and laboratory heating value data for an average of representative switchgrass grab samples, was used to estimate the total heat content that was provided by the biomass facility to the OGS boiler. That information was used in monthly fuel supply billings from Chariton Valley RC&D Inc. to Alliant Energy / IPL and in monthly reports submitted by Alliant / IPL to environmental agencies. Example fuel supply invoices and monthly processing reports from each month of the Long Term Test Burn are provided in Appendix S and Appendix H, respectively.

The operation of the moisture detection was accurate when checked periodically with bales tested with hand held moisture probe. The moisture meter did not interfere with the movement of the bales and required no recalibration during the test.

The load cells arrived at an accurate average weight for a collection of bales whenever they were calibrated, although weight of individual bales varied. The project team periodically checked the calibration of the load cell weight results against results from the portable digital platform scale and adjusted load cell calibrations as needed. Bale weight became a useful indication to the operator about the density or moisture of the bale and the probable operation in the debaler and eliminator. For commercial production, recording bulk weight with a truck scale is recommended. Load cells might also be used to check-weigh incoming bales and for process control purposes.

4.4.3 Twine Removal

Previous test burns showed that automated twine removal is essential to switchgrass processing. Manual removal could not keep up with production at a rate of 12.5 tph or 25 bales per hour or more. The debaler can grind some bales with twine, but the twine itself becomes shredded or "balls up" and creates plugging or problems downstream in the feed screws, rotary airlocks, and pneumatic conveying equipment. Short-term operation without experiencing major problems when grinding twined bales should not be considered proof that long-term grinding of bales without twine removal will be problem-free or desired.

Procurement during the Interim Test Burn showed that European suppliers would not supply affordable twine removal equipment to the U.S. The debaler supplier was convinced to apply a concept they had used for small bales to large bales so the project used the "destringer" supplied by Warren & Baerg. The detringer worked well for the Interim Test Burn. A low rate of failure was recorded during a 1600 bale run and several suggestions were made for mechanical and controls improvement. Those improvements were incorporated into the destringer for the LTB.

During the LTB is was clear that the low rate of failure in the Interim Test Burn was due to the fact that the 1600 bales were of uniform size, shape, and had all been supplied by the same contractor. Wide variation in bale height and density made it necessary to modify the destringer for variable bale height. A hydraulic lift table and top of bale position sensor were added to the destringer. The cutter must be adjustable through 12 inches of height. Standard bales are 35 to 38 inches in height whereas some bales supplied were as small as 24 inches. Cutter and bale lift fingers were also required for development. The cutter itself went though several different designs before a satisfactory blade design was developed that would function reliably without dragging straw through the bale. The rake finger for removing the twine also had to be modified many times during the burn.

A long term solution was not found for twine disposal during or after the LTB. In the West, twine is collected and recycled. A similar source should be sought for commercial production which will generate several tons of twine per month. Twine disposal should be organized prior to commercial operation.

4.4.4 Debaling

4.4.4.1 Capacity and Performance

The debaler was sized and tested during the Interim Test Burn. At that time, the infeed of the debaler was run semi-automatically for periods up to 10 hours per day. Capacities on clean dry straw were measured up to 15 tph. Capacity reduced with variation in the uniformity of the bales and increased moisture. It is clear over the long term that the average capacity is 10 tph for the existing system with a 2-inch screen. Capacity typically varied with bale quality from about 8 tph to 14 tph over sustained periods, with lower production rates occurring when processing wet bales, poorly packaged bales, and/or bales with a high content of fine grasses such as Foxtail. The higher production rates were achieved when processing lower moisture content bales that were well-packaged and consistent, and with a high content of switchgrass and/or woody-stemmed weeds.

4.4.4.2 Power Consumption

Two 200 hp motors were selected for the debaler based on previous tests and expected loads. The rotors are designed for a maximum of 250 hp. New 250 hp debaler motors should be purchased for commercial operations to allow peak capacity to handle wet and dense bales—this will reduce the frequency of triggering high-current fault conditions in the control system which in turn automatically stop bale infeed momentarily to the conveyor until motor loads reduce.

Average power consumption for the debaler reducing bales using a 2-inch screen, as shown in Exhibit 44 and Exhibit 45, was a function of bale moisture content. Exhibit 44 shows a summary of power consumption data for both the debaler ("DB") and the Eliminator mill ("HM"). To generate each point in the graph, Antares selected sustained periods of time during the test burn during which moisture contents were relatively constant. Exhibit 45 shows examples of several such periods. For bale moisture contents less than about 14%, average power consumption for the debaler alone was about 12 kWh/ton and ranged consistently between about 10 to 14 kWh/ton. Above moisture contents of 14%, there was a steady increase in power consumption per ton processed with average rates as high as 24 kWh/ton. The design power consumption rate was: 2 x 200 hp / 12.5 tph = 32 hp/tph x 0.746 kW/hp = 24 kWh/ton. As power requirements increased with moisture and bale density, production rates reduced.

Another factor affecting debaler motor power consumption was bale height. As bale height varies, the infeed height of the bales should be adjusted to balance the load between the rotors. When the load is not balanced, one of the rotors (usually the bottom) will surge and overload—this results in stopping production. An insert installed during the test burn raised the bale feed to the center of the rotors and balanced motor loads between the top and bottom debaler motors and improved production rates.

Exhibit 44 Mill (HM) & Debaler (DB) Power Ratio vs. Moisture Content

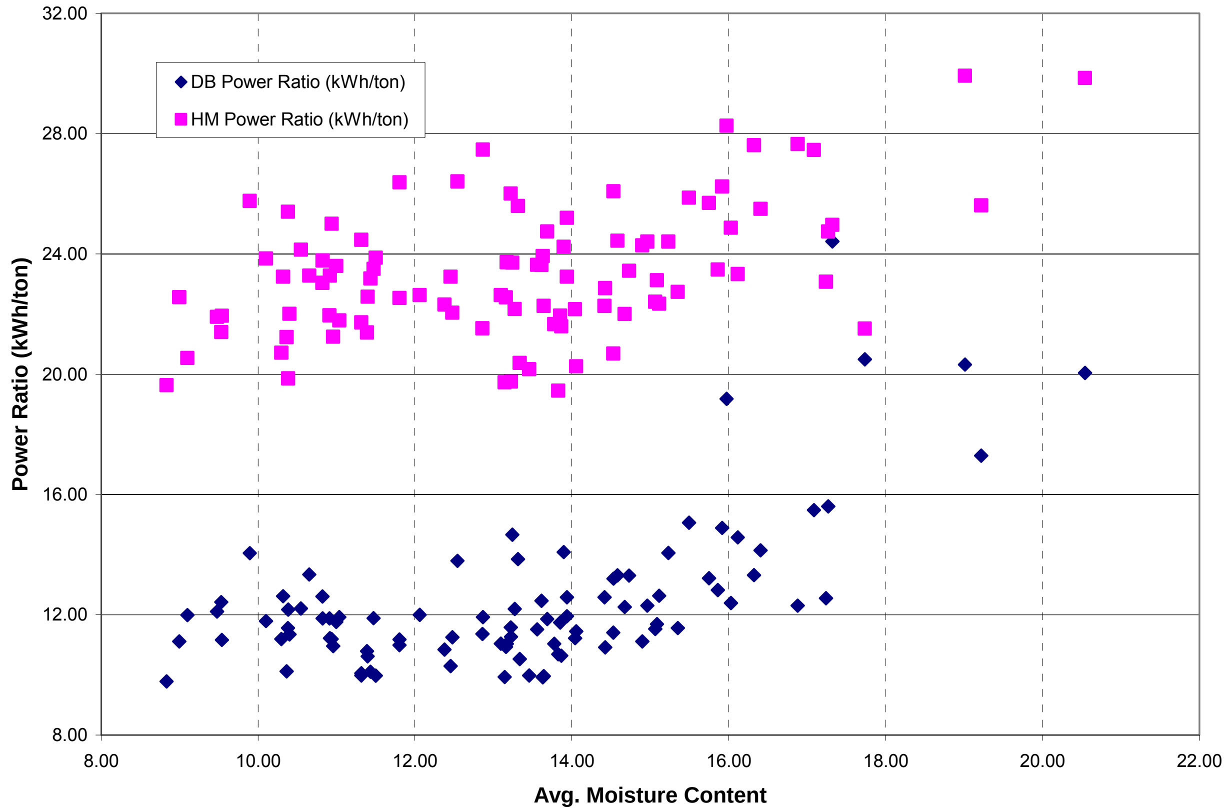


Exhibit 45 Sample of Data from Power Analysis

Date	3/14/2006	3/14/2006	3/15/2006	3/15/2006	3/15/2006	Date of sample
Start	0:30:00	11:00:00	0:01:00	6:15:00	1:00:00	Time range for sample
End	6:30:00	16:00:00	6:01:00	12:15:00	7:00:00	
Duration	6:00:00	5:00:00	6:00:00	6:00:00	6:00:00	
Bale Count	134	93	166	111	163	Bales processed during sample period
Average MC	**13.69**	**16.88**	**13.14**	**16.03**	**13.46**	Data obtained from Daily Bale files written on client computer
Max MC	18	23	17	25	20	
Min MC	11	11	11	7	11	
Median MC	13	17	13	16	13	
Modal MC	13	16	13	15	13	
Std Dev MC	1.53	2.54	1.36	2.87	1.74	
Tons Processed	59.77	49.05	71.03	59.53	70.80	
Average Weight (lbs)	**892**	**1,055**	**856**	**1,073**	**869**	
Overall Average Weight (lbs)	892	1,055	856	1,073	869	
Max Weight (lbs)	1,132	1,178	1,094	1,325	1,236	
Min Weight (lbs)	807	816	791	796	791	
Std Dev Weight	91	81.97	50	118	69.58	
Average Feed Rate (tons/hr)	**13.31**	**12.66**	**11.88**	**12.62**	**12.10**	
Overall Avg Feed Rate (tons/hr)	9.96	9.81	11.84	9.92	11.80	
Max FR (tons/hr)	16.41	16.18	14.84	16.13	16.13	
Min FR (tons/hr)	0.00	8.42	0.00	8.98	0.00	
Std Dev FR	1.39	1.45	1.16	1.32	1.27	
DB Usage (kWh)	708.80	603.32	704.92	737.57	706.58	Calculated from daily power files written on client computer
HM Usage (kWh)	1478.67	1356.10	1401.41	1480.40	1427.63	
DB Demand (kW)	118.13	120.66	117.49	122.93	117.76	
HM Demand (kW)	246.44	271.22	233.57	246.73	237.94	
Power Ratio (kWh/ton)	**36.60**	**39.95**	**29.65**	**37.26**	**30.14**	
DB Power Ratio (kWh/ton)	**11.86**	**12.30**	**9.92**	**12.39**	**9.98**	
HM Power Ratio (kWh/ton)	**24.74**	**27.65**	**19.73**	**24.87**	**20.16**	

4.4.4.3 Maintenance and Repair

Screens and hammers were expected to be the major maintenance requirement for the debaler. Based on prior experience with similar crops, the hammers were expected to last 20,000 tons and the screens 30,000 tons. The hammers are in good shape after processing over 15,000 tons. The screens were replaced at about 8,000 tons due to wear. The screens were made of mild steel. It is likely that longer screen wear is possible with higher grade alloys.

4.4.4.4 Safety

There is an access door on the side of the debaler. Access is necessary for clearing jams and changing screens. A door switch interlock was anticipated for the access door. In practice, lock out-tag out procedures were observed. Confined space procedures, including use of a combustible and toxic gas detector, were also used prior to allowing operators to enter the debaler.

4.4.4.5 Fire Protection

One fire occurred at the debaler. A larger piece of metal was heated by the spinning hammers. When a material plug occurred, the hot metal started a fire in the infeed chamber. A fire crew put out the smoldering straw before it flamed into a major fire. Nozzles should be installed on the debaler infeed to allow flooding the infeed in case of fire or the appearance of combustible gas.

4.4.4.6 Improvements

A new second debaler should be installed to ensure production rates of 12.5 tph. Debaler motors should be increased to 250 hp. Debaler infeed should be adjustable to the height of the bale to balance load on the motors. Fire suppression should be available at the debaler infeed. Higher alloy screens should be used for longer screen wear. There should be an auxiliary outfeed at the debaler to bypass the secondary grinder or prepare straw for other uses.

4.4.4.7 Conveying Debaled Switchgrass

An outfeed belt (718 conveyor) was used to convey debaled switchgrass to the secondary grinder. The belt was used so that a magnetic belt conveyor could be used to separate metal before reaching the secondary mill. The belt conveyor was textured to help move the straw. Switchgrass frequently stalled on the outfeed conveyor causing plugs. It should be replaced by a flight conveyor or pneumatic discharge.

A pneumatic discharge would have the advantage of providing an opportunity for an air rock separator and less straw inventory between the primary and secondary grinder. Pneumatic discharges are used in some Warren & Baerg applications where hay or straw is ground to 3/16-inch or less for pelleting or cubing. A pneumatic discharge could also help increase production capacity of the debaler by providing suction of processed material through the debaler screens, thus helping reduce the probability of material collecting on the screens and causing plugging within the debaler.

4.4.4.8 Dust Removal

Minimal dust removal was provided at the debaler infeed and outfeed due to budget limitations. While this operation was ordinarily reasonably clean over time, the fine dust from the debaler accumulates in the building and presents a health hazard. A second dust collector should be installed to remove process dust.

4.4.5 Metal Removal

A belt magnet was installed after the debaler to remove metal before entering the secondary grinder. The belt was timed to run intermittently to remove any metal that was in the debaled switchgrass. While important quantities of metal were removed, it was judged after 15,000+ tons that it was not necessary to use a belt magnet. A permanent magnet at the head pulley would remove most metal.

The belt magnet also became a major source of dust. As the belt moved it fanned dust off the conveyor. Enclosing a belt conveyor is more difficult than a permanent magnet.

4.4.6 Secondary Milling

4.4.6.1 Eliminator Capacity, Performance and Product Quality

During the system design it was decided to continue to use the attrition grinder, called the "Eliminator," which was used in the initial tests and interim burn instead of changing to a conventional hammermill which is used in Denmark. Wear during processing of the first 1000 tons had been minimal and when the eliminator is fed uniformly at a steady load the particle size was suitable for cofiring and good burnout. Capacities during the interim test had been confirmed at 12 to 14 tph so it was thought there would be enough capacity for the long term test. In general, the Eliminator did produce an acceptable milled product. However during testing several observations were made about the capacity, performance, and product quality (as described below).

4.4.6.2 Capacity

The attrition grinder, which depends to some degree on particle-to-particle attrition for milling, works best with dry straw. In general, particle sizing was good and the product fed to the boiler was consistent.

Wet straw reduced attrition grinding and absorbed horsepower just as it had with the debaler. Production was reduced considerably with wet straw. High volumes of wet straw also would not evacuate efficiently from the grinder. The accumulated straw absorbed horsepower and exceeded available power shutting off the infeed and sometimes overloading the motor. The mill needs a uniform feed to it for uniform production.

Switchgrass flow to the Eliminator was controlled by feed to the debaler. Additional overload controls were added to the 718 infeed conveyor. If wet switchgrass built up in the eliminator, the 718 conveyor was stopped along with the infeed to the debaler so that the inventory on the 718 conveyor did not flood the eliminator infeed. Alternatively a pneumatic transport could be used between the debaler and eliminator to reduce the inventory in transport.

After the Interim Test Burn, the infeed to the Eliminator was modified to improve straw flow into the rotors. This improved straw flow and no infeed plugs were experienced. Outfeed airflow and vacuum was also increased which improved material flow through the grinder. Straw did not back up into the infeed as it had in the Interim Burn. In general, flow through the mill was good when the mill was not overloaded by an inventory of wet switchgrass. It was possible to increase the feed rate to the Eliminator so that it was consuming 80% of its maximum current during most times.

After 7500 tons, vibration occurred in one rotor which caused the Eliminator to be off balance. On inspection it was found that a rotor was cracked, so the rotor was replaced. The root cause was identified as a defective weld in the rotor assembly. At the inspection, the inside housing of the Eliminator was found to be severely worn. The heads were worn off of the bolts holding the rotor hammers. And the hammers themselves were severely worn on the leading edge especially in the first third of the length of travel. Hammer wear had expected to be in excess of 50,000 tons. Hammers were replaced with a slightly heavier hammer design. Other alloys should be investigated for better wear resistance.

Rocks, metal and other foreign matter did not seem to affect the operation of the Eliminator. Pieces that had been milled to less than 2 inches and were missed by the magnet were trapped downstream of the Eliminator by an air separator and rock trap. This was the primary reason for using the Eliminator compared with a standard hammer mill in the first place.

Standard hammer mills should be investigated to replace the attrition grinders for full commercial operation. Operation in Denmark has shown that this will require more frequent maintenance of hammers and screens but that it will result in fewer long term outages.

4.4.6.3 Power Consumption

Each of the two rotors on the Eliminator is driven by a 300 hp motor. The design power consumption rate was: 2 x 300 hp / 12.5 tph = 48 hp/tph x 0.746 kW/hp = 36 kWh/ton. As was the case with the debaler, and as shown in Exhibit 44 and Exhibit 45, power consumption per ton of switchgrass processed was also a function of bale moisture content. For bale moisture contents less than about 18%, average power consumption for the Eliminator alone was about 24 kWh/ton and ranged consistently between about 20 to 28 kWh/ton. Above moisture contents of 18%, there was an increase in power consumption per ton processed with average rates as high as 30 kWh/ton.

In comparison to the debaler, the average operational load of the Eliminator was much closer to its designed capacity from a motor horsepower persective—there was less reserve capacity designed into the Eliminator as compared to the debaler. This was expected and had been measured and monitored in detail during a series of processing tests performed in August 2004. Detailed results from those tests are provided in Appendix I. As the tests in August 2004 showed, the loads on the Eliminator are also impacted significantly by the size of the material being fed to it. As photos of processed material samples in Appendix I demonstrate, the size of material leaving the Eliminator is fairly consistent regardless of the size of the material being fed into it (even though the Eliminator operates with no screens). As expected, the amount of horsepower required to process larger infeed material is higher on a kWh per ton basis. In comparison, the debaler is much less sensitive to increased power consumption as the size of screen openings is reduced (i.e., as the particle size leaving the debaler is reduced).

As shown by the example data in Exhibit 45, the average electrical demand for the

Eliminator ranged from about 230 to 275 kW while the average electrical demand for the debaler was in much narrower range around 120 kW. The Eliminator and debaler represented about 50% and 25% of the total facility average electrical operating load, respectively. Combined, these two machines represented about 75% of the facility's average operating electrical demand.

4.4.7 Low Pressure Conveyor

Switchgrass exiting the secondary grinder or eliminator was discharged into a pneumatic conveying line to contain dust and provide a negative pressure in the Eliminator. Rocks and metal were separated in a rock separator in the horizontal duct run under the Eliminator. In practice, not much collected in the secondary rock separator. Switchgrass was discharged from a high efficiency cyclone to the meter bin. Clean air from the top of the cyclone passed through a dust collector and induced draft fan. The low pressure system operated satisfactorily with no major maintenance issues during the 1700 hours or 15,000+ tons of operation.

Spark Detection was provided in the conveying lines and in the dust collection lines. The system used is an industry standard and provided few problems. Lightening upset the low voltage electricity providing a false ground which triggered the quench nozzles and flooded the conveying line on one occasion. The quench nozzles triggered a few times probably due to sparklers from the secondary grinder.

4.4.8 Surge/Meter Bin

Processed fuel discharged to the surge or meter bin. The meter bin has two pairs of screws and is intended to divide the flow of the switchgrass between the two conveying lines to the OGS boiler. During previous tests it was learned that maintaining a low level in the bin and running the screws at full rpm was the best way to handle the milled switchgrass. Too much buildup in the surge bin can cause bridging as found in Denmark and elsewhere.

As switchgrass discharged from the cyclone through an airlock it would swirl preferentially to one side so a deflector was installed to provide an even flow to each side. Fuel distribution appears to be consistent and predictable in the metering bin. The loads on each of the screws were similar. The deflector was adjusted so that the backpressure in each of the conveying lines was similar. Vibration sensors on each conveying line also provide a relative signal (in decibels) that indicated even flow in the conveying lines.

The deflector occasionally had to be cleaned. Balls of plastic fiber from the twine would accumulate on the deflector. This was the only location where twine caused a noticeable problem. It may have caused some temporary plugging in the conveying lines but never stopped flow.

Level in the meter bin was monitored using an ultrasonic level control. Two sonic sensors provided an average level signal that was suitable for monitoring the level. It was not expected to signal an alarm.

The two pairs of screws in the bin have been in service since the initial firing tests in 2000. The drive shafts and gear boxes should be inspected and repaired before commercial operation.

A diverter gate should be installed below the airlock so that milled switchgrass could be diverted to an alternate process when the feed to the boiler is stopped for some reason.

Fine dust from the baghouse was returned to the surge bin and sent to the boiler with the milled fuel. Fines can be diverted at the baghouse if they need to be used for other purposes or higher value uses. The tube conveyor used in the interim test burn was used for the return conveyor from the baghouse to the surge bin. A new fine dust flight conveyor should be used to return the fines.

4.4.9 Blowers, Airlocks and Transport Lines to Boiler

Switchgrass from the surge bin was discharged through rotary airlocks into two high pressure conveying lines for transport to the boiler. The pneumatic system consists of the high pressure blowers, adjustable deflector, rotary airlocks, pipe and fittings, and nozzles that discharge the milled switchgrass into the boiler.

The high pressure blowers were sized for a maximum conveying pressure of 7 psi. Typical system pressure at full load was 4.5 psi. Load on the motors was fairly constant. As material built up or wet material was conveyed, the pressure would swing. In general the conveying system operated well as long as the lubricators were operational and there was a steady feed of switchgrass to the conveying lines.

Blower control consisted of a high pressure limit switch which would shut off the feed to the conveying line at a pressure below the maximum operating pressure and a high pressure or overpressure limit that would stop the blowers if one of the lines were plugged. At times the feeder to the pneumatic line would stop when there was high backpressure in a line. Usually balancing the flow between lines solved this condition. The only time the blowers stopped or overloaded was on restarting with a loaded line. Usually a couple of restarts would clear the lines. Plugged lines never stopped operation.

The airlocks will need repair before restarting operation. During testing in 2003, the airlocks were not purged with air to keep the seals clear. During storage between test burns, water leakage had caused rust damage in one of the airlocks. There had been some seal misalignment which was repaired at startup. Purge air was added to the operation which improved airlocks jamming due to seals. Purge air must be supplied to both airlocks. This will have to be made permanent in the installation if operations continue. The airlocks will have to be shipped to the supplier and inspected or rebuilt prior to commercial operation.

Conveying lines stayed clear to the boiler house during the operation. The schedule 40 pipe appears to have held up well for the first 1,700 hours of operation. Conveying lines inside the building at OGS will have to be replaced since they were made of lighter, 20 gauge steel. All elbow and expansion joints should be replaced from where the switchgrass enters the building to the nozzles into the boiler. These bends did not survive the abrasive switchgrass and were frequently repaired as the test progressed. When IPL boiler house operators noticed a leak in a switchgrass pipe during the test burn (due to ground switchgrass leaking out of the pipe and into the boiler house), biomass processing facility supervisors would immediately shut the biomass system down, repair the pipe leak in the boiler house, and would clean up the ground switchgrass on the boiler house floors before restarting the biomass processing system.

Controls for the pneumatic conveying system included the pressure switches listed above, pressure gauges at the blowers, and acoustic sensors. During operation it was clear that transmitters should be installed to communicate the line pressure back to the control panel. The acoustic sensors had been used with success in the 2003 tests to balance the loading between the conveying lines. The conveying pressure provides additional information about the loading on each conveying line. Pressure increases with wet fuel and with higher loadings. New transmitters should be installed and incorporated into system controls prior to commercial operation. The acoustic sensors have served their purpose and can be removed.

4.4.10 Ottumwa Generating Station

At OGS the conveying lines inside the plant were installed in 2000 with Schedule 20 pipe. Elbows and expansion joints were not carefully planned. The piping, elbows and expansion joints inside the boiler house should be replaced with expansion joints suitable for handling hot or cold boiler conditions. Switchgrass caused significantly more abrasion than expected at the elbows, so abrasion resistant elbows should be used. In addition, the inner diameter of several expansion joints were slightly smaller than the inner diameter of the switchgrass conveying pipes on either side of the expansion joints. This created a natural area for increased abrasion along the inner diameter of the expansion joints and these areas were among the most prone for leaks to occur. Replacement expansion joints should be sized to avoid this problem. There are isolation valves at the nozzles. The seals of these gate valves and their air actuators of should be inspected.

As switchgrass enters the burner it transitions from a round pipe to a square discharge. Combustion air is delivered around the flow of switchgrass from the boiler wind box. The switchgrass burners were installed with the pitch control fixed, so no adjustments were made to the burners during the burn. Inspections of the burner showed no plugging or agglomeration around the burner or on the burner walls.

Communications and controls with OGS were effective once all of the OGS operators and OGS shift supervisors got used to them. There was frequent telephone communication between the Switchgrass and OGS controls rooms. Continuous electronic communication between control systems at each facility was anticipated throughout the burn period, and was installed and tested to confirm functionality, but was not fully utilized due to post-911 security concerns. Six key performance parameters from the switchgrass facility were continuously fed into the OGS data acquisition system to allow Alliant Energy performance engineers and OGS staff to independently monitor switchgrass operations and impacts on the plant. Those parameters, as discussed further in Chapter 3, were: bale weight, switchgrass feed rate (tons/hr), bale moisture content, switchgrass feed on/off for each pneumatic supply line, and bale reject conveyor cycling to record when off-spec bales were rejected.

4.4.11 Baghouse and Dust Collection

Excess capacity in the process dust collector was used for environmental dust collection at key pickup points through the process to reduce the airborne dust levels from accumulating within the processing facility. Airborne dust within the facility was a significant problem during the early part of the commissioning activities and several workers could not continue working during that period because of the high amount of dust in the facility. Installing additional dust pickups at key locations of dust generation within the processing system kept the dust levels down in the working area to a level acceptable to most employees. This had been the experience during the tests in 2003, but due to budgetary reasons, an additional dust collector was not purchased for the Long Term Burn. A dust collector for environmental control should be added for commercial operation to ensure a clean work environment. This will not completely remove potential biological hazard from handling straw due to bacteria, but it will reduce the risk. Dust pickups should be added in key areas such as the debaler and the secondary grinder. The baghouse was effective in removing dust prior to discharge to the environment. This was confirmed in compliance tests during the first 180 days of the LTB, which demonstrated that dust emissions levels from the baghouse fan exhaust were well below the manufacturer's guaranteed levels. Dust from the process can be returned to the surge bin where it will be sent to the boiler, thereby eliminating any waste from the dust collection operation.

4.4.12 Auxilary Systems

Auxiliary systems in the straw processing system included compressed air, fire protection, and communications. Fire protection was incorporated into the building controls. The compressor for the fire system needs to be repaired to prevent unnececcary alarms due to reduced pressure. A permanent air compressor must be procured for the building and process if commercial operations continue. It should supply sufficient capacity for both process and maintenance purposes.

4.4.13 System Controls and Communication

Process controls and instrumentation installed were suitable for all process tasks, data trending, and data communication to the OGS data management system. The PLC (Programmable Logic Controller) system controlling the process was reprogrammed several times to solve challenges due to variability in switchgrass quality and to provide uniform flow of switchgrass to the moisture detector, weigh scales, destringer, debaler, secondary grinder, and pneumatic conveying system.

Variable frequency drives were used to control all elements requiring adjustment to speed. All drives were adequately sized.

Communications within the building used hand-held radios with a speaker system. This system had intermittent capacity. An antenna to extend the range around the building should be installed. Communication with OGS could be improved by arranging for a secure channel of electronic communication in addition to the existing data transfer. Flashing warning lights were also used at several locations within the process line to alert operators of items in need of maintenance or attention.

4.4.14 Power

Electrical power consumption was less than originally anticipated. Motor loads were generally anticipated. Actual power consumption was higher for bale conveyors than were originally anticipated based on experience in 2003, however all drives were adequately sized. Changes to bale conveyors will relieve some of the excess load due to bale drag on the conveyor floors. Additional power will be required to add a second process line, auxiliary dust collection, and waste straw handling thExhibit 14at will ensure the reliability of straw delivery year round.

4.4.15 Spares

A full suite of spares was not procured for the LTB. Spares were obtained as they became necessary. However, a full set of spares would need to be included in a budget for full production.

5 Technical Results from Test Burns

The purpose of this chapter is to summarize the key test results from the project's test burns, and to relate the meaning of those measured results to potential future commercial operations. Brief summary results for each of the three test burns were also provided in Chapter 2. Since the most recent and also the longest test burn was the "Long Term Test Burn" that was conducted between February and May of 2006, most of the information presented in this chapter is from that test or the activities that led to gaining approvals for that test. Overall, the primary areas for measuring results from the test burns were: 1) biomass processing facility operational costs and performance, including power consumption and processing rate capabilities; 2) fuel and ash properties; 3) air emissions; 4) unburned carbon in fly ash and bottom ash; 5) fly ash performance in concrete, and 6) longer-term impacts potential for boiler heat exchange surfaces (fouling, slagging, and corrosion impacts).

5.1 Processing Results and Statistics

As summarized in Exhibit 14, an approximate total of about 17,720 tons of switchgrass were processed and burned in the OGS boiler during the project's three test burns. A total of about 15,671 tons, or about 31,627 bales of switchgrass were processed and sent to the OGS boiler during the Long Term Test Burn in about 1,675 hours of burn time. Average delivered moisture content was about 13 percent and the average as-received heating value was estimated at about 6,950 Btu/lb based on laboratory fuel analyses for selected fuel samples, and moisture content measurements for every bale processed. The average bale weight was 991 pounds.

Detailed daily, weekly, and monthly biomass processing reports were produced throughout the test burn to inform project partners and other interested parties about the test burn activities and progress. The daily reports, provided for each day of the test burn are provided in Appendix F. Those reports were distributed via e-mail each morning throughout the test burn along with a written summary of the previous day's activities, maintenance issues, and other noteworthy items. Weekly summary reports, shown in Appendix G, were produced for Chariton Valley RC&D Inc. and PrairieLands BioProducts board member updates. The weekly reports included updates of the estimated revenue that would have been accrued by the week's processing activities according to the draft Commercial Sales Contract Agreement between IPL and PrairieLands BioProducts. Monthly processing summary reports are provided in Appendix H—these reports were required for environmental reporting purposes and were submitted to OGS plant staff at the beginning of each month for the prior month's biomass supply to the OGS boiler. The monthly summaries were required to contain measured results for daily biomass tons delivered to the boiler, average daily moisture content, and total monthly heat content supplied from biomass.

Testing for the Long Term Test Burn started on February 16, 2006 and was completed on May 12. Exhibit 46 provides a summary of the average daily results during the final month of the test burn. During that period, an average of 232 tons per day were processed and delivered to the OGS boiler. The processing system was on-line and processing over 22 hours per day, or 92% of the time. During processing, the average biomass feed rate through the system was about 10.5 tons per hour. On a 24 hour basis, the average processing rate during the final month was 9.6 tons per hour. This 24-hour rate includes down time due to maintenance and other system stoppages. For the final two weeks, processing results were even better with an average of 248 tons per day processed during 23 hours of average daily system run time (system was processing 96% of the available time), for an average processing rate close to 11 tons per hour.

Exhibit 46 Long Term Burn Average Daily Processing Results (Final Month)

Final Month Biomass Processing Statistics		
Average bales per day	474	bales/day
Average tons per day	232	tons/day
Average system run time per day	22.1	hrs/day
Average availability (run time / total hours)	92%	
Average feed rate during run time	10.5	tons/hr
Overall average feed rate (based on 24 hr/day)	9.6	tons/hr

Exhibit 48 and Exhibit 49 are charts showing the number of tons and bales processed each day throughout the test burn, respectively. As can be seen in the charts, daily production was lower in the early weeks of the test. During that period, equipment, controls, and operating procedures were being adjusted and improved to a greater extent than in the latter weeks of the test. *The higher daily production in the final weeks of the test was primarily the result of two factors: 1) process and operational improvements implemented early in the test period, and 2) pre-screening inventoried bales to obtain higher quality, lower moisture content bales for processing.* The maximum tonnage processed in a single day was 265 tons (on May 4), and the average daily processing rate for the whole test period was 182 tons. The maximum number of bales processed in a single day was 620 (on May 11), and the average number of bales processed per day was 368. The period at the end of March where no processing occurred for more than four days was caused by a fracture in one of the rotor shafts on the “Eliminator” which performs the second stage of size reduction. Production was halted during that period until the rotor could be replaced.

Each chart also includes a line for daily average moisture content. The final month of the test burn is most representative of how this processing system would perform during commercial operations since most system and procedural improvements had been implemented by that time in the test. The general trend of increased daily production rate for lower average moisture contents during the final month of the test burn is an important observation. That trend is not obvious during the early weeks of the test burn when equipment and controls improvements were impacting daily production rates due to down-time required to make the upgrades; however, even during those periods it was very apparent to system operators that increased bale moisture contents led to increased processing difficulties (higher power consumption, more material plugging, etc.), process line outages to clear bridged material, and decreased feed rates.

Exhibit 50 and Exhibit 51 show daily system run time and weekly system availability throughout the test burn period, respectively. Daily run time was measured and recorded by the control system, and was a measure of the time when all equipment in the system was in run-mode, not stopped by the system operator for maintenance or other operational reasons. As shown in Chapter 3, Exhibit 20, the lead operator could stop any conveyor or key systems (dust system, vacuum system, all systems except the blower, or all systems at once) through the touch screen controls if processing difficulties occurred. Any time a piece of equipment was in stop mode was not counted towards the daily system run time total. Exhibit 50 shows lower and more sporadic daily run times during the early weeks of the test burn as equipment and controls were being adjusted and improved. Daily run times improved throughout the test burn and variations from day to day became less extreme. By the end of the test, daily run times were consistently above 22 hours. The average daily run time during the final two weeks was 23 hours, or 96% of the total available time. Exhibit 51 shows weekly system availability, measured as the total weekly system run time divided by the total number of hours per week. After the initial two weeks of operation, with the exception of the period when the “Eliminator” rotor failed and caused a 4+ day system outage, the system availability was above 80%. During the final month the average system availability was 92%, and during the final two weeks it was 96%. The overall availability for the entire test period, neglecting the initial two weeks of operation when system commissioning activities were occurring, was 81%. That figure includes all outage and stoppage time after the second week of operations. Because system improvements were still being incrementally implemented throughout the test burn, and because the unusual “Eliminator” rotor shaft failure caused what could be expected to be an unusually long unplanned outage, system availability of 90% or above is a reasonable expectation for potential future commercial operations.

Exhibit 47 shows the ranges and averages for daily biomass feed rates throughout the test period, both for periods when the processing system was operating (labeled “During Run Time” in the exhibit) and on a 24-hour basis that includes all system stoppages. While the processing system was operating, biomass feed rates through the system averaged 10.8 tons/hr, with daily averages ranging from 9.1 to 13.1 tons/hr. The daily average feed rates during run time could be viewed as the limit of this system’s processing rate capabilities for switchgrass if all daily stoppage time could be eliminated. On a 24 hour basis including all stoppage time, daily feed rates averaged 9.0 tons/hr, with daily averages ranging from 5.8 to 11.1 tons/hr. Including the 4+ day outage period in late March, the average feed rate for the test burn on a 24-hour basis was about 8.4 tons per hour.

Exhibit 47 Long Term Burn Daily Feed Rate Results (Average and Range)

Daily Average Feed Rates *	During Run Time	24-hour Period
Minimum:	9.1 tons / hr	5.8 tons / hr
Maximum:	13.1 tons / hr	11.1 tons / hr
Average:	10.8 tons / hr	9.0 tons / hr

* Neglects first 2 weeks, and outage period at the end of March.

Exhibit 52 shows average daily biomass feed rates, during run time, throughout the test burn. It should be noted that Exhibit 52 does not include lost production time due to system stoppages. Reviewing Exhibit 52, one can see that average feed rates during run time were higher in general before the 4+ day system outage at the end of March than the average feed rates were after the outage. The average feed rate during run time before the outage was about 11.7 tons/hr, and the average after the outage was about 10.4 tons/hr. However, the daily tonnage processed after the outage was higher on average (as shown in Exhibit 48). Before the outage, lead system operators attempted to maximize daily production by attempting to run the system at the highest possible feed rate. While this practice did lead to higher feed rates for short periods of time, it also increased the frequency of problems which required maintenance outages to correct (material bridging/plugging, etc.). During the outage, changes were implemented to the control system to allow lead system operators to run the system in a more automated mode. The result was reduced daily outage time and improved total daily tons processed, even when the system was set to run at feed rates that were about 15 percent less than feed rate settings before the outage.

Exhibit 53 provides maximum daily feed rates throughout the test burn. The maximum feed rates are based on ten bale batches (the maximum feed rate throughout the day for processing ten consecutive bales). Depending on the feed rate, the ten bale batches typically took between 15 and 30 minutes to process. Daily maximum feed rates were typically in the 14 to 16 ton/hr range, with the highest feed rates recorded being on the order of 20 tons/hr.

Exhibit 48 Long Term Test Burn Daily Tons Processed

Exhibit 49 Long Term Test Burn Daily Bales Processed Bales Processed

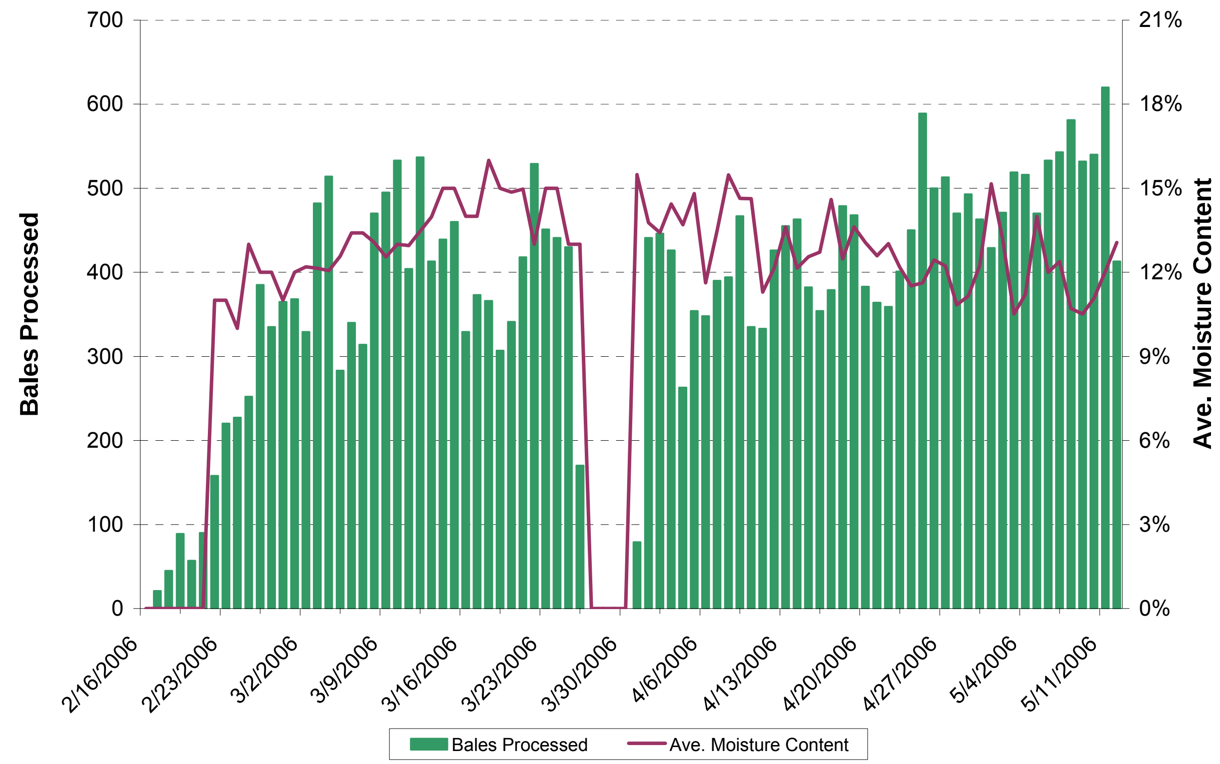


Exhibit 50 Long Term Test Burn Daily System Run Time

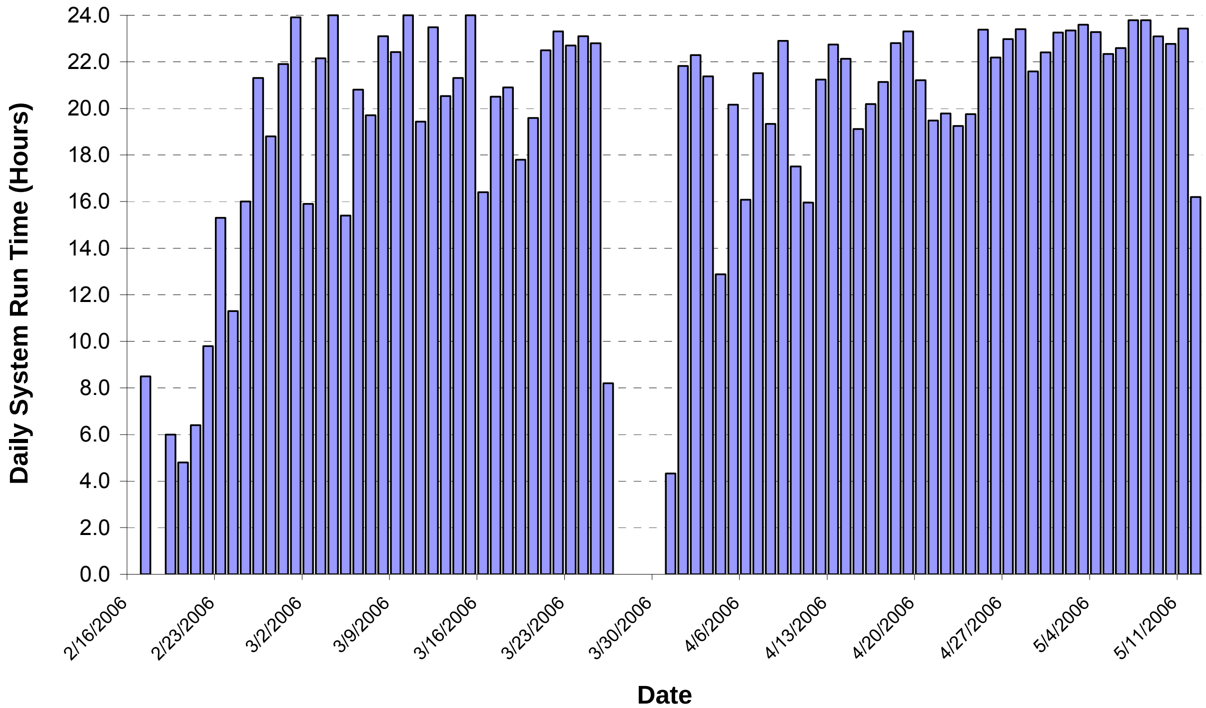


Exhibit 51 Long Term Test Burn Weekly Processing System Availability

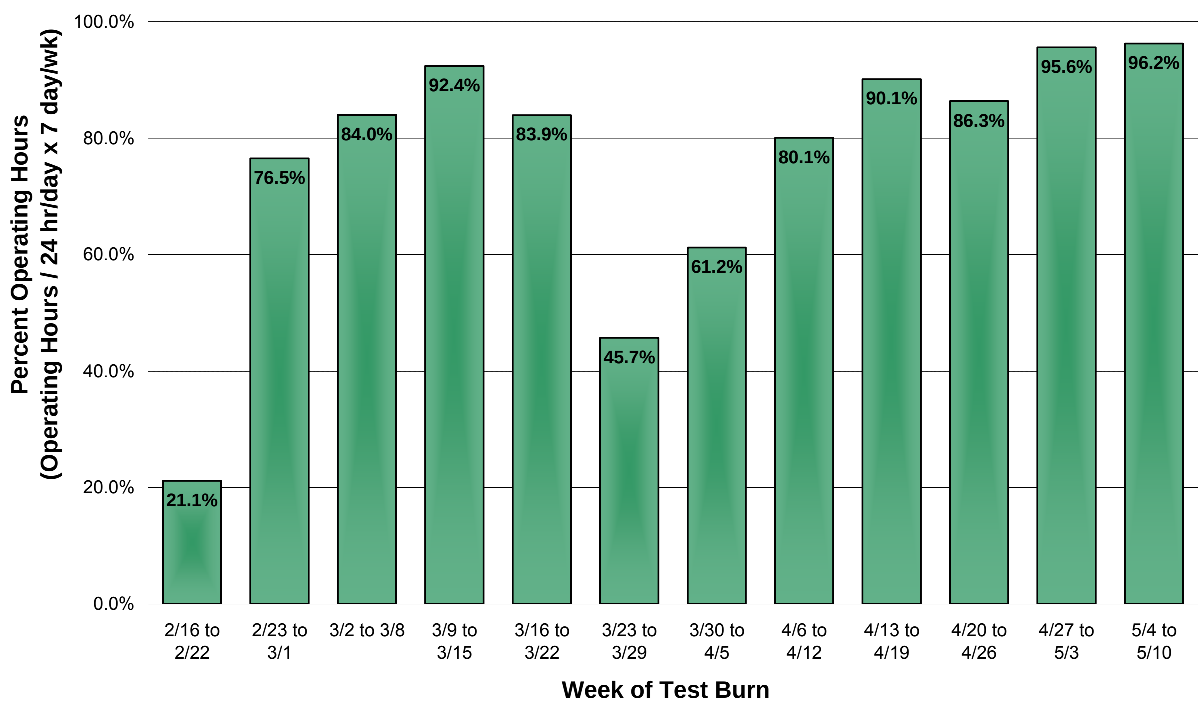


Exhibit 52 Long Term Test Burn Average Biomass Feed Rates (During Run Time)

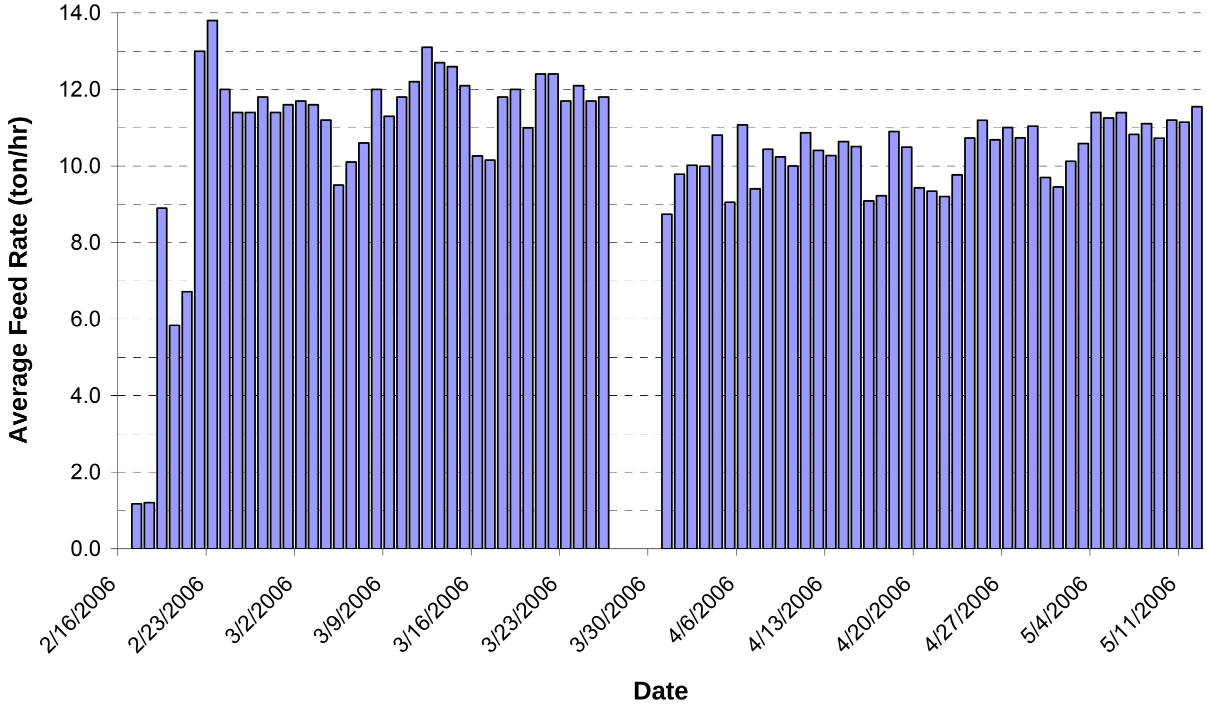


Exhibit 53 Long Term Test Burn Maximum Biomass Feed Rates by Day

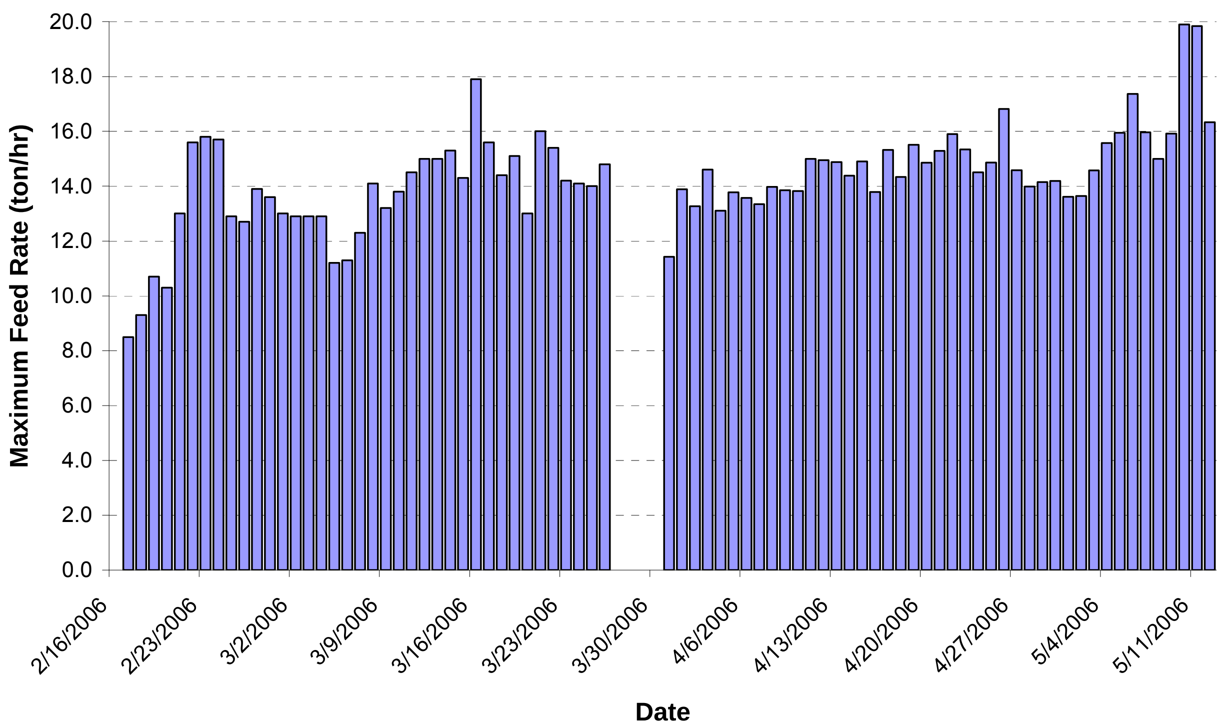


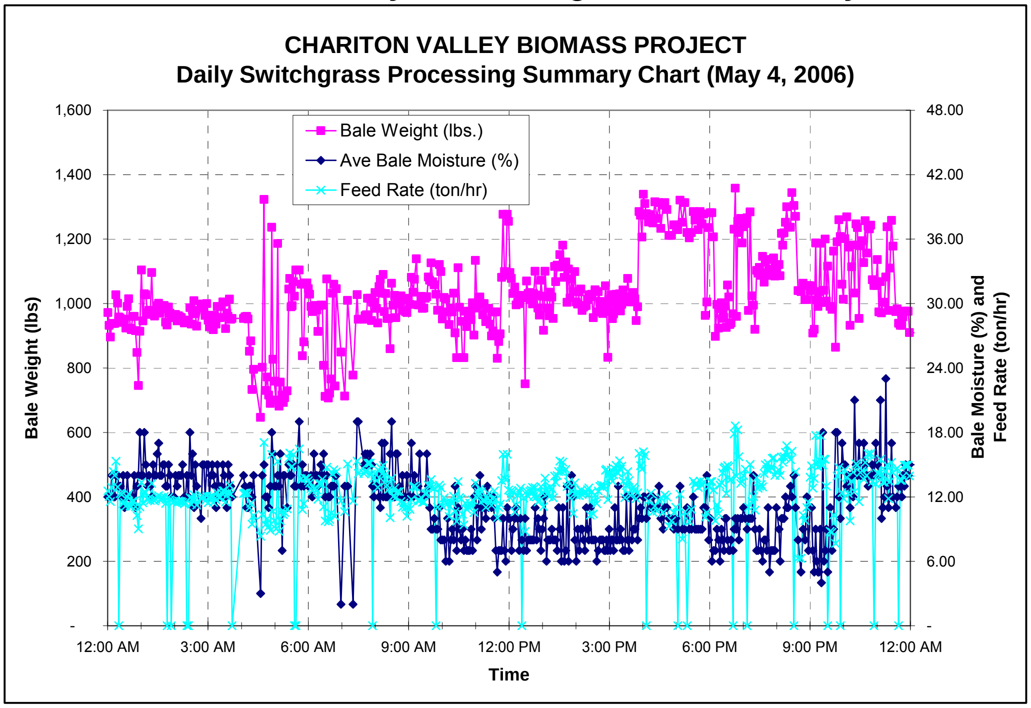
Exhibit 54, Exhibit 55, and Exhibit 56 show daily processing summaries for the best processing day of the test (May 4), a problematic processing day, and a typical processing day, respectively. Similar charts and summary tables were created and distributed to all project team members and interested parties throughout the test burn following each day's operation. All daily processing charts from the test burn period are provided in Appendix F. Each chart shows the measured moisture content, weight, and the processing feed rate for each bale processed throughout the day.

May 4 was the most productive day of the test burn. A total of 516 bales were processed and over 265 tons of switchgrass was supplied to the OGS boiler. The average feed rate for the day was over 11 tons per hour, the average bale moisture content was relatively low at 11 percent, and there was only 0.7 hours (42 minutes) of system stoppage time. A summary of processing activities on this day is provided in Exhibit 54.

Exhibit 55 shows the summary for a more problematic processing day during which average bale moisture content was relatively high at about 15.5 percent. In the early morning hours between 12 am and 5 am, one can see that as bale moisture content decreased, average processing feed rates steadily increased. An extended system stoppage occurred between about 7 am and 9 am, and the total system stoppage time for the day was about 4.7 hours. This pattern of decreased feed rates with increased bale moisture contents, and increased down time was typical when processing bales with higher moisture content.

Exhibit 57 shows an example of a monthly switchgrass processing report. These reports were prepared by the project team for each month throughout the test burn, and were submitted immediately following the end of each month. The reports were required to be submitted to Alliant Energy / IPL for inclusion in their monthly environmental reporting for fuel and heat input at OGS. The requirements of the report were to catalog daily tons burned and average daily moisture content throughout the month, total tonnage burned and overall average moisture content for the month, and the total heat content of the switchgrass for the month (adjusted to the actual measured moisture content of the fuel). During the test burn, these reports were generated manually in spreadsheets using the daily switchgrass processing summaries shown in Appendix F. If commercial biomass cofiring operations begin at OGS in the future, these and several of the other reports generated throughout the test burn should be automated to reduce the cost and time required for report preparation.

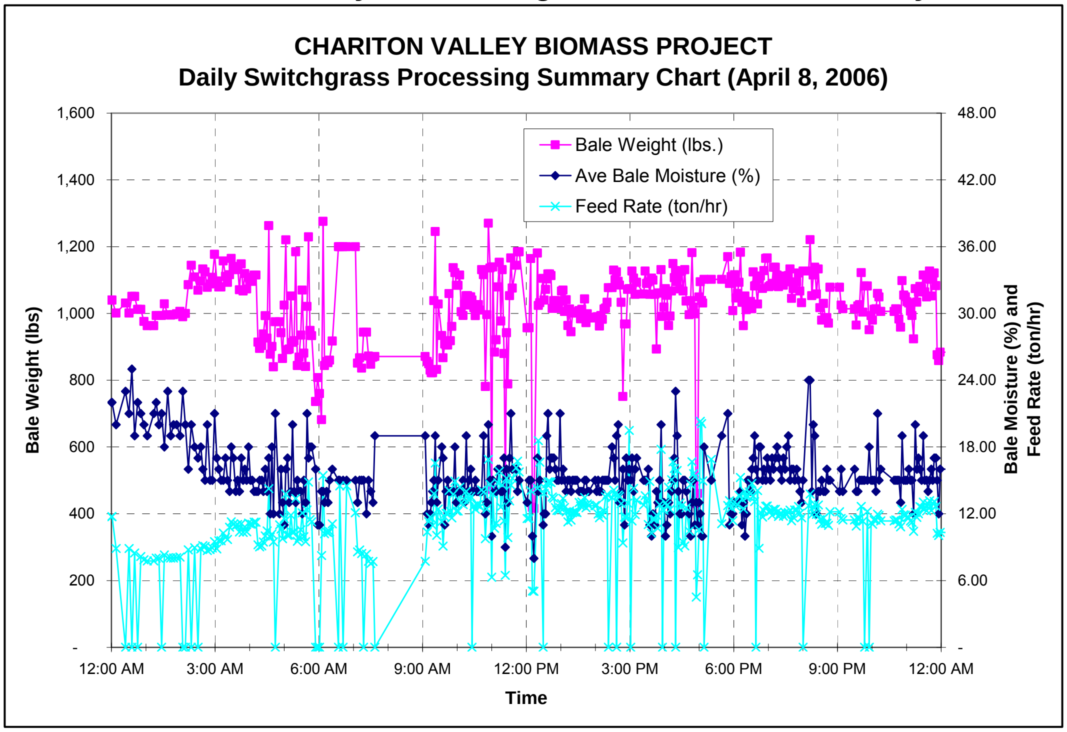
Exhibit 54 Daily Processing Profile: Best Day



Summary Statistics:

Date :	Thursday, May 04, 2006			
Bale Count :	516	bales		
Run Time :	23.3	hrs		
Total Bale Weight :	265.3	tons		
Max. Bale Weight :	1,358	lbs.		
Min. Bale Weight :	647	lbs.		
Average Bale Weight:	1,028	lbs.		
Average Moisture Content:	11%			
Max. Bale Moisture :	23%			
Min. Bale Moisture :	2%			
Average Feed Rate (as recorded for each bale):	12.2	tons/hr ;	3.2	ft/min.
Max. Feed Rate (ten bale average):	15.6	tons/hr ;	4.1	ft/min.
Min. Feed Rate:	-	tons/hr ;	-	ft/min.
Average Feed Rate: (Daily Tons / Daily Runhours)	11.4	tons/hr ;		
Diff Between Avg. Feed Rates:	7%	Setpoint vs. Actual During Run Hours		
Overall Avg. Feed Rate: (Daily Tons / 24 hrs)	11.1	tons/hr		
Diff Between Avg. Feed Rates:	9%	Setpoint vs. Actual Overall		

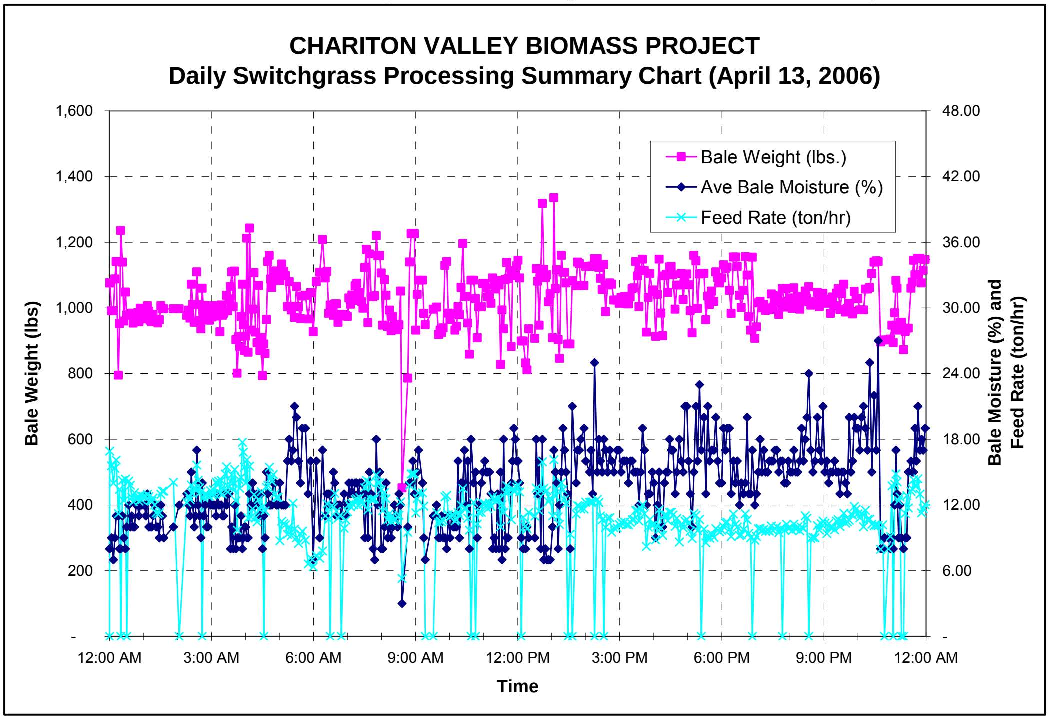
Exhibit 55 Daily Processing Profile: Problematic Day



Summary Statistics:

Date :	Saturday, April 08, 2006			
Bale Count :	394	bales		
Run Time :	19.3	hrs		
Total Bale Weight :	201.9	tons		
Max. Bale Weight :	1,276	lbs.		
Min. Bale Weight :	416	lbs.		
Average Bale Weight:	1,025	lbs.		
Average Moisture Content:	15.47%			
Max. Bale Moisture :	25%			
Min. Bale Moisture :	8%			
Average Feed Rate (as recorded for each bale):	11.0	tons/hr ;	2.9	ft/min.
Max. Feed Rate (ten bale average):	14.0	tons/hr ;	5.2	ft/min.
Min. Feed Rate:	-	tons/hr ;	-	ft/min.
Average Feed Rate: (Daily Tons / Daily Runhours)	10.4	tons/hr ;		
Diff Between Avg. Feed Rates:	6%	Setpoint vs. Actual During Run Hours		
Overall Avg. Feed Rate: (Daily Tons / 24 hrs)	8.4	tons/hr		
Diff Between Avg. Feed Rates:	24%	Setpoint vs. Actual Overall		

Exhibit 56 Daily Processing Profile: Normal Day



Summary Statistics:

Date :	Thursday, April 13, 2006			
Bale Count :	455	bales		
Run Time :	22.7	hrs		
Total Bale Weight :	233.6	tons		
Max. Bale Weight :	1,335	lbs.		
Min. Bale Weight :	452	lbs.		
Average Bale Weight:	1,027	lbs.		
Average Moisture Content:	14%			
Max. Bale Moisture :	27%			
Min. Bale Moisture :	3%			
Average Feed Rate (as recorded for each bale):	10.9	tons/hr ;	2.8	ft/min.
Max. Feed Rate (ten bale average):	14.9	tons/hr ;	4.7	ft/min.
Min. Feed Rate:	-	tons/hr ;	-	ft/min.
Average Feed Rate: (Daily Tons / Daily Runhours)	10.3	tons/hr ;		
Diff Between Avg. Feed Rates:	6%	Setpoint vs. Actual During Run Hours		
Overall Avg. Feed Rate: (Daily Tons / 24 hrs)	9.7	tons/hr		
Diff Between Avg. Feed Rates:	11%	Setpoint vs. Actual Overall		

Exhibit 57 Sample Monthly Process Report (April)

Switchgrass Processing Date	Switchgrass Processed (tons)	Average Moisture Content
1-Apr-06	213.5	13.8%
2-Apr-06	223.3	13.4%
3-Apr-06	213.6	14.4%
4-Apr-06	139.2	13.7%
5-Apr-06	182.5	14.8%
6-Apr-06	178.0	11.6%
7-Apr-06	202.3	13.5%
8-Apr-06	201.9	15.5%
9-Apr-06	234.4	14.6%
10-Apr-06	175.0	14.6%
11-Apr-06	173.4	11.3%
12-Apr-06	221.0	12.1%
13-Apr-06	233.6	13.6%
14-Apr-06	235.5	12.2%
15-Apr-06	200.9	12.6%
16-Apr-06	183.4	12.7%
17-Apr-06	194.9	14.6%
18-Apr-06	248.6	12.5%
19-Apr-06	244.5	13.6%
20-Apr-06	200.0	13.1%
21-Apr-06	181.9	12.6%
22-Apr-06	182.0	13.0%
23-Apr-06	188.0	12.2%
24-Apr-06	211.9	11.5%
25-Apr-06	261.7	11.6%
26-Apr-06	237.1	12.4%
27-Apr-06	252.9	12.2%
28-Apr-06	251.2	10.8%
29-Apr-06	238.3	11.1%
30-Apr-06	217.3	12.2%
Monthly Totals	**6,321.7**	**12.5%**

HHV (as received) = (1-MC) x HHV (dry basis)

HHV (as received, est contract avg)		
HHV (dry basis)	7,956	Btu/lb
MC (est. contract avg.)	13.4%	
HHV (as received, est contract avg)	6,892	Btu/lb
HHV (as received, actual for month)		
HHV (dry basis)	7,956	Btu/lb
MC (actual this month)	12.5%	
HHV (as received, actual for month)	**6,962**	**Btu/lb**
Total MMBtu	**88,017**	**MMBtu**

NOTE: HHV = Higher Heating Value (the heat content of the biomass fuel)

5.2 Fuel Properties from Test Samples

During periods of the Interim Test Burn and the Long Term Test Burn when emissions stack testing or short-term fouling tests were being performed at OGS, coal and switchgrass samples were collected, labeled according to sample type, date and time collected, and test description (cofiring or coal-only), and sent to Consol Energy's testing laboratory in Pittsburg, PA for detailed analysis. During the same periods, fly ash, bottom ash, and economizer ash samples were collected and sent to Consol's lab for detailed analysis. The detailed sample descriptions and specifications for the laboratory tests for the samples collected during the Interim Test Burn and the Long Term Test Burn are provided in Appendix K, along with the resulting laboratory test results from each test burn period. Results from the fuel sample tests are described in this section, and ash test results are discussed later in this chapter. Switchgrass samples for laboratory analysis were collected from the surge bin in the biomass process facility since the material in the surge bin was fully processed and ready to be sent to the OGS boiler. Coal samples were collected by OGS plant staff from the coal belt that delivers coal from the coal yard to the coal bunkers in the boiler house.

5.2.1 Chemical Properties of Coal & Switchgrass

During the Interim Test Burn, detailed laboratory analyses were performed on 12 coal samples (one for each test day) and 8 switchgrass samples (one for each cofire test day). Detailed laboratory analyses included: ultimate and proximate analysis[23] with heating value; sulfur, chlorine, alkali, and RCRA[24] trace metal (Ag, As, Ba, Cd, Cr, Hg, Pb, Se) content; major ash elements; and ash fusion temperatures. More limited analyses were performed on an additional 47 switchgrass samples to allow a thorough characterization of key parameters throughout the test period. The limited analyses included: proximate analysis with heating value; and sulfur, chlorine, and mercury content. Selected summary results that are relevant to air emissions, including the relative change in the *blended* fuel properties (as compared to coal-only) resulting from the addition of switchgrass at a 2% heat input rate (shown in the right column of the table), are shown in Exhibit 58 and summarized below:

- The average heating values of coal and switchgrass were 8,940 Btu/lb and 7,480 Btu/lb, respectively, on an as-received basis at the laboratory.

- Average moisture contents for coal and switchgrass samples were 25% and 6%, respectively. It should be noted that the average moisture content of switchgrass as obtained by probing bales and on-site use of an IR moisture balance was higher than the samples analyzed in the laboratory, with the in-field

[23] An Ultimate Analysis measures the fuels fraction of moisture, carbon, hydrogen, nitrogen, sulfur, ash, and oxygen. The Ultimate analysis enables the calculation of the higher heating value (HHV). A Proximate Analysis measures the faction of moisture, ash volatile and fixed carbon.

[24] RCRA, which stands for Resource Conservation and Recovery Act, is a major piece of environmental law that among other things created regulation of hazardous wastes including toxic metals.

measurements averaging about 13%. As-received heating value estimates of the switchgrass were adjusted accordingly, yielding an average as-received heating value of 6,892 Btu/lb for the switchgrass samples.

- The average ash contents were 6.1 lb/MMBtu and 6.2 lb/MMBtu for coal and switchgrass (on a dry basis), respectively. On an as-received basis, ash contents averaged 8.1 lb/MMBtu for coal and 6.6 lb/MMBtu for switchgrass.

- The column labeled "Switchgrass / Coal Ratio" in Exhibit 58 provides the ratio of each measured property for switchgrass as compared to the same property in the coal fired during the test. On a dry basis, the switchgrass samples had about 70 percent of the heating value of coal. On a heat content basis (lb/MMBtu), switchgrass had 50 percent of the fuel-bound nitrogen compared to coal, 3.5 times the amount of fuel-bound oxygen, 30 percent of the sulfur content, 35.1 times the chlorine content, about the same ash content, 5.7 times the total alkali content (K and Na), 20 percent of the total RCRA trace metal content, and 40 percent of the mercury content.

- The right-hand column in Exhibit 58 shows the relative change in the *blended* fuel properties (as compared to coal-only) resulting from the addition of switchgrass at a 2% heat input rate. The blended fuel samples had a 0.7 percent lower heating value than coal. On a heat content basis, the blended fuel would have a 1.1 percent lower fuel-bound nitrogen than coal, a 5 percent higher amount of fuel-bound oxygen, a 1.3 percent lower sulfur content, a 68 percent higher chlorine content, about the same ash content, 9.4 percent higher total alkali content (K and Na), a 1.6 percent lower total RCRA trace metal content, and a 1.3 percent lower mercury content.

Exhibit 58 Summary of Selected Average Coal and Switchgrass Properties

Fuel Property	Units	Average Coal Sample	Average Switchgrass Sample	Switchgrass / Coal Ratio	Relative Change in BLENDED Fuel (2% SWG)
As-Received Basis					
Moisture	% weight	24.8	6.0	0.2	
Moisture	lb/MMBtu	27.7	8.0	0.3	
Ash	% weight	5.5	4.6	0.8	
Ash	lb/MMBtu	8.1	6.6	0.8	-0.4%
Sulfur	% weight	0.31	0.09	0.3	-1.4%
Chlorine	% weight	0.002	0.059	29.4	56.8%
Mercury (Hg)	lb/trillion Btu	10.3	3.0	0.3	-1.4%
Higher Heating Value (HHV)	Btu/lb	8,942	7,479	0.8	-0.3%
Dry Basis					
Higher Heating Value (HHV)	Btu/lb	11,893	7,956	0.7	-0.7%
Nitrogen	lb/MMBtu	0.85	0.40	0.5	-1.1%
Oxygen	lb/MMBtu	14.7	51.4	3.5	5.0%
Sulfur	lb/MMBtu	0.35	0.12	0.3	-1.3%
Chlorine	lb/MMBtu	0.002	0.079	35.1	68.3%
Ash	lb/MMBtu	6.1	6.2	1.0	0.0%
Total Alkalis (K & Na)	lb/MMBtu	0.07	0.43	5.7	9.4%
Total RCRA Trace Metals	lb/MMBtu	0.025	0.005	0.2	-1.6%
Mercury (Hg)	lb/trillion Btu	7.7	2.8	0.4	-1.3%

Exhibit 59, Exhibit 60, and Exhibit 61 present the ranges and averages for proximate and ultimate analyses, RCRA trace metals, and major ash elements and properties from the Interim Test Burn laboratory analyses, respectively. Results in these exhibits are the basis for the information presented in Exhibit 58. As in Exhibit 58, both Exhibit 60 and Exhibit 61 include a column on the right-hand side that contains the ratio of each measured quantity in switchgrass as compared to coal (in the column labeled "SWG / Coal").

As shown in Exhibit 60, on a dry weight basis, all measured RCRA trace metals were significantly lower in switchgrass than in coal, with the exceptions of chromium and selenium. On a dry weight basis, silver (Ag), arsenic (As), and mercury (Hg) were about 20 percent as high in switchgrass as compared to coal, barium (Ba) was about 10 percent as high, cadmium (Cd) was about 60 percent as high, and lead (Fe) was about 30 percent as high. Chromium (Cr) was 1.6 times higher in switchgrass and selenium (Se) was about the same as in coal. For a 2% blend (on a heat input basis) of switchgrass with coal, that translates to overall increases of 1.9% for chromium and 0.5% for selenium and reductions in all other RCRA trace metals.

As shown in Exhibit 61, on a dry weight basis, major ash constituents that were higher in switchgrass as compared to coal were: SiO_2 (1.8 times higher), Fe_2O_3 (1.3 times higher), K_2O (22 times higher), and P_2O_5 (4.1 times as high). Switchgrass-to-coal ratios for major ash constituents that measured lower in switchgrass ash were: Al_2O_3 and TiO_2

(0.1), CaO (0.3), Na_2O (0.2), and SO_3 (0.3). MgO was present in switchgrass ash in about the same quantity as in coal ash on a dry weight basis.

Detailed test results and summary tables from the Long Term Test Burn laboratory analyses are provided near the end of Appendix K. Coal and switchgrass laboratory test results from the Long Term Test Burn were compared to those presented above from the Interim Test Burn, and results were very comparable on all properties. A total of 8 coal samples and 11 switchgrass samples were sent for laboratory analysis from the Long Term Test Burn. Results from those analyses were also used by Elsam / Danish Oil & Natural Gas (DONG) for completing their analyses for estimating the potential long-term impacts (slagging, fouling, and corrosion) of cofiring switchgrass at OGS.

Exhibit 59 Summary of Proximate and Ultimate Analyses for Daily Fuel Samples

Sample Type =>	COAL				DEBALED SWITCHGRASS			
Statistic	*Average*	*Min.*	*Max.*	*Count*	*Average*	*Min.*	*Max.*	*Count*
	Proximate + Btu Analysis (As-received basis)							
Moisture, %	24.80	23.13	25.88	12	5.99	5.44	8.29	8
Vol. Matter, %	33.33	32.18	33.86	12	72.24	70.64	74.02	8
Fixed Carbon, %	36.10	35.25	37.07	12	16.99	15.88	17.52	8
Ash, %	5.45	4.11	7.95	12	4.63	4.08	5.27	8
Sulfur, %	0.31	0.29	0.33	12	0.09	0.07	0.12	8
Chlorine, %	0.00	0.00	0.00	12	0.06	0.03	0.08	8
Btu/lb (HHV)	8,942	8,680	9,114	12	7,479	7,410	7,579	8
	Proximate + Btu Analysis (dry basis)							
Vol. Matter, %	44.34	41.86	45.52	12	76.85	75.82	78.64	8
Fixed Carbon, %	48.43	47.80	49.88	12	18.23	17.03	18.71	8
Ash, %	7.24	5.49	10.34	12	4.92	4.33	5.60	8
Btu/lb (HHV)	11,893	11,292	12,107	12	7,956	7,836	8,115	8
MAF Btu/lb.	12,821	12,594	12,951	12	8,368	8,248	8,501	8
	Ultimate Analysis (dry basis)							
Ash, %	7.24	5.49	10.34	12	4.92	4.33	5.60	8
Carbon, %	69.15	65.98	70.20	12	47.99	47.58	48.51	8
Organic C, %	68.98	65.97	70.19	10	47.98	47.58	48.51	8
Inorganic C, %	0.01	0.01	0.01	10	0.01	<0.01	0.02	8
Hydrogen, %	4.70	4.37	5.04	12	5.70	5.63	5.78	8
Nitrogen, %	1.02	0.92	1.08	12	0.32	0.17	0.50	8
Oxygen, %	17.48	16.90	18.66	12	40.91	40.39	41.77	8
Sulfur, %	0.41	0.39	0.45	12	0.09	0.07	0.13	8
Chlorine, %	0.00	0.00	0.00	12	0.06	0.04	0.08	8
ppm Chlorine	27	13	45	12	627	361	850	8

Exhibit 60 Summary of RCRA Trace Metals Analyses for Daily Fuel Samples

Sample =>	COAL				DEBALED SWITCHGRASS				SWG /
Metals	*Ave.*	*Min.*	*Max.*	*Count*	*Ave.*	*Min.*	*Max.*	*Count*	Coal
	RCRA Trace Metals, ppm Dry Weight Basis (except where noted)								
Ag	0.05	0.04	0.06	10	0.01	0.01	0.01	8	0.2
As	1.10	0.76	1.40	10	0.24	0.09	0.54	8	0.2
Ba	294.00	261.40	325.65	10	35.32	24.35	65.86	8	0.1
Cd	0.08	0.05	0.11	10	0.05	0.02	0.10	8	0.6
Cr	3.72	2.55	6.31	10	6.05	3.29	8.81	8	1.6
Hg	0.09	0.07	0.12	12	0.02	0.02	0.03	8	0.2
Pb	2.44	2.01	2.88	10	0.73	0.38	1.11	8	0.3
Se	0.77	0.54	1.22	10	0.79	0.53	1.22	8	1.0

Exhibit 61 Summary of Major Ash Elements & Properties for Daily Fuel Samples

Sample =>	COAL				DEBALED SWITCHGRASS				SWG /
Statistic	*Ave.*	*Min.*	*Max.*	*Count*	*Ave.*	*Min.*	*Max.*	*Count*	**Coal**
	Water Soluable Alkali (ppm dry basis, except where noted)								
Soluble Na	490	440	520	10	55	46	60	8	**0.1**
Soluble K	34.3	25.2	42.6	10	3,533.4	2,365.0	4,948.0	8	**103.0**
	Major Ash Elements, Wt % Ash (Ignited to 750 Deg. C)								
SiO2	34.45	30.53	44.76	10	60.81	57.62	62.75	8	**1.8**
Al2O3	16.75	13.98	19.84	10	1.53	1.23	2.04	8	**0.1**
TiO2	1.37	1.17	1.91	10	0.09	0.07	0.11	8	**0.1**
Fe2O3	4.73	3.96	5.42	10	6.12	3.74	10.11	8	**1.3**
CaO	22.37	15.72	24.83	10	9.81	9.15	10.36	8	**0.4**
MgO	3.85	3.02	4.12	10	3.85	3.28	4.55	8	**1.0**
Na2O	1.25	0.98	1.41	10	0.31	0.20	0.39	8	**0.2**
K2O	0.37	0.15	0.77	10	8.03	6.01	9.64	8	**22.0**
P2O5	1.25	0.74	1.63	10	5.17	4.12	5.96	8	**4.1**
SO3	12.06	8.50	14.08	10	3.25	2.85	3.76	8	**0.3**
Oxide Total	98.45	97.65	99.73	10	98.95	97.56	100.45	8	

5.2.2 Bulk Density and Particle Size for Processed Switchgrass

Although particle size and bulk density (weight per cubic foot of material) measurements for processed switchgrass were not high priorities during the project test burns, some testing was performed to characterize these parameters. Material bulk densities are important for hauling, storing, and conveying material. The higher the bulk density, the more weight of material can be hauled/stored/conveyed within a certain fixed volume of space. Exhibit 62 provides a summary of the bulk density results from the bales weighed during the Interim Test Burn. For 347 bales weighed during the ITB, the bale weights ranged from 740 to 1075 pounds, averaging about 900 pounds each. Corresponding minimum, average, and maximum bulk densities for the 3 ft x 4 ft x 8 ft bales were 7.7, 9.4, and 11.2 lb/ft^3, respectively. Debaled switchgrass samples were collected from the belt on the inclined conveyor which delivered debaled switchgrass from the debaler discharge to the “Eliminator” inlet chute. Ground switchgrass samples were collected from the discharge of the baghouse (during the Interim Test Burn, all ground material passed through the baghouse because no separate cyclone was installed). The bulk densities of the debaled switchgrass averaged 2.6 lb/ft^3 and ranged from 2.4 to 2.9, while ground switchgrass averaged 6.6 lb/ft^3 and ranged from 5.9 to 7.5.

Exhibit 62 Switchgrass Bulk Density Results from Interim Test Burn

	Switchgrass Bulk Density (lb/ft^3)		
Statistic	**Baled**	**Debaled**	**Ground**
Minimum	7.7	2.4	5.9
Average	9.4	2.6	6.6
Maximum	11.2	2.9	7.5
No. of Samples	347	14	14

Towards the end of the Long Term Test Burn, a series of tests were performed using batches of similar bales. The objective of the batch testing was to process large enough quantities of each of the prevalent bale types encountered throughout the test burn to enable conclusions to be drawn regarding the additional costs involved when processing less than optimal bales. Detailed information on processing costs and characteristics were collected throughout the processing of each batch. Bales were sorted at the storage facilities into batches with similar characteristics. Six types of bale batches were assembled in quantities of about a single trailer's payload (42 bales). Each batch was then delivered to the processing facility, and each batch was processed separately. The types of batches tested were:

- High switchgrass content, low moisture content,
- High switchgrass content, high moisture content,
- High foxtail content,
- Loosely packaged bales,
- High woody weed content bales (also referred to in this section as "wildlife mix"), and
- Bottom bales (bales that had been stored on the bottom of stacks and tended to be higher in moisture and dirt content, and were more often misshaped or had other problems not common in bales stored elsewhere in the stacks).

While the majority of material in most bales processed throughout the test was switchgrass, the fields that were harvested varied in the type and quantity of other species. Some harvesters skipped areas of the field where switchgrass density was lower, while others harvested and baled those areas. The result was baled material that had varying characteristics which impacted the operations at the processing facility in different ways. During the batch testing, material samples were collected after the debaling process and after the grinding process to roughly characterize processed bulk densities of the different types of material encountered during the Long Term Test Burn. Exhibit 63 summarizes the results. Bulk densities of the baled material ranged from about 9 to 11 lb/ft^3. The debaling process decreased the bulk densities to roughly one-third to one-half of the baled densities, with debaled bulk densities ranging from 3.0 to 5.4 lb/ft^3. After the grinding process, bulk densities ranged from only 5.0 lb/ft^3 for the high foxtail content (and high moisture) bales to 11.9 lb/ft^3 for the high woody weed content bales. The high switchgrass content, low moisture content bales also ground to a higher bulk density than most other materials, at 11.1 lb/ft^3.

Exhibit 63 Bulk Density Results from Long Term Test Burn

Bale Batch Type	Debaler Screen Size	Bale Moisture	Switchgrass Bulk Density (lb/ft^3)		
			Baled	Debaled	Ground
High Switchgrass Content, Low Moisture	1 inch	9%	10.1	3.0	11.1
High Switchgrass Content, High Moisture	1 inch	16%	11.1	4.3	7.0
High Switchgrass Content, High Moisture	2 inch	15%	11.2	3.3	7.9
High Foxtail Content	1 inch	17%	11.1	3.0	5.0
"Wildlife Mix" (High woody weed content)	1 inch	12%	9.3	5.4	11.9

Exhibit 64 through Exhibit 66 show debaled and ground samples of three of the types of materials tested during the bale batch tests, and discussed above. The ground material is what was supplied to the OGS boiler. Additional photos of processed biomass samples are provided in Appendix I for various debaler screen sizes and bale content.

Exhibit 64 Debaled and Ground Samples, High Switchgrass Content

Exhibit 65 Debaled and Ground Samples, High Foxtail Content

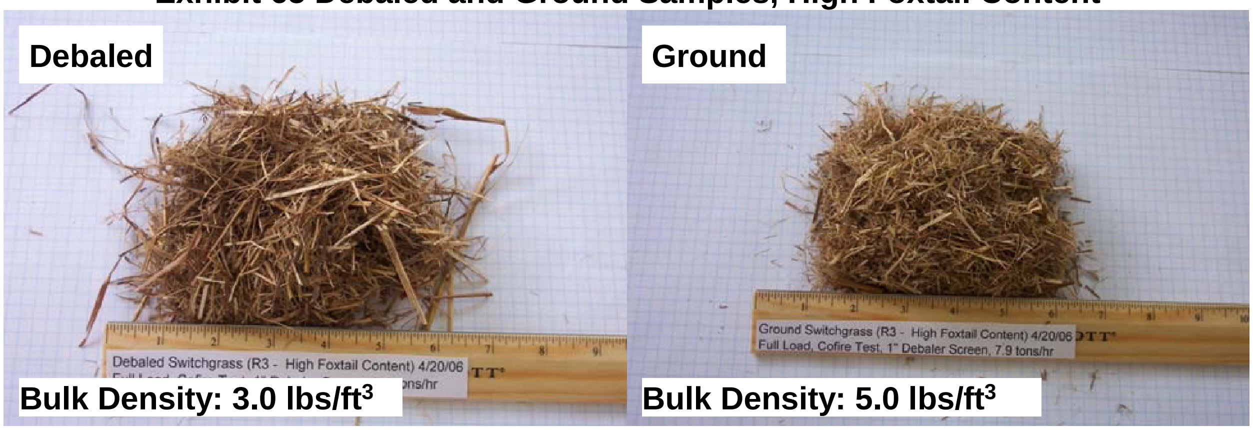
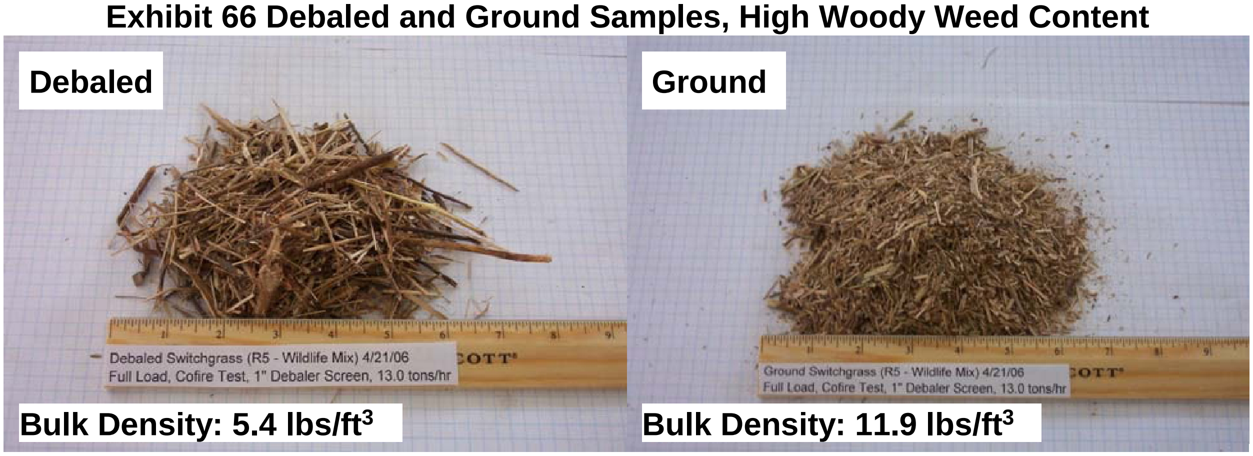
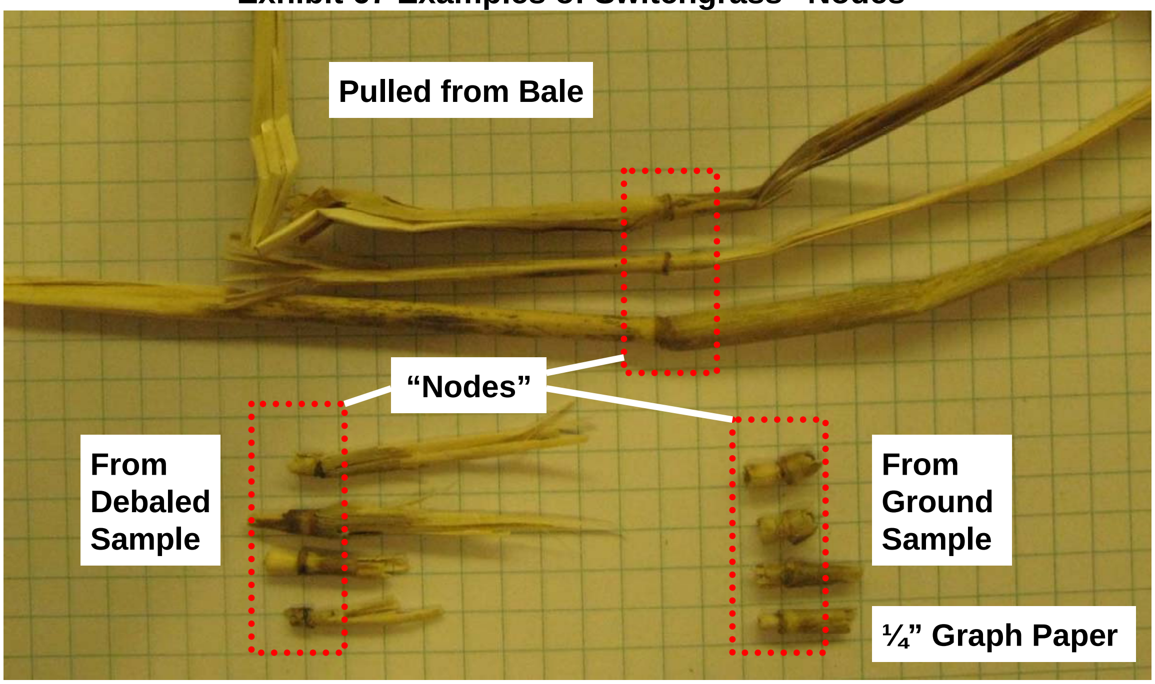


Exhibit 66 Debaled and Ground Samples, High Woody Weed Content



Based on observations of fly ash and economizer ash samples collected at various times during the test burns, the particle sizing of this ground material seemed to provide very good burn-out in the OGS boiler. The large majority of the unburned biomass particles, which were the larger, heavier pieces, dropped to the bottom of the furnace and exited the boiler in the bottom ash. The unburned biomass was typically either switchgrass "nodes" or pieces of non-switchgrass species such as goldenrod. Switchgrass "nodes" are located between two adjacent sections of stalk, and are significantly harder to grind and burn compared to the rest of the plant. Exhibit 67 shows examples of switchgrass "nodes" in samples pulled from a bale, from a sample of debaled material, and from a sample of ground material. While the shafts of the plant was significantly broken down from one process step to the next, the nodes tended to stay intact to a much greater extent, including upon injection into the OGS furnace. Additional information on unburned biomass in boiler ash streams is provided later in this chapter.

Exhibit 67 Examples of Switchgrass "Nodes"



Eleven samples of ground switchgrass were collected during the Long Term Test Burn and analyzed for particle size distribution. Exhibit 68 shows the particle size distributions for those samples. The bars represent the average percent of the sample weight that was collected in the mesh size range indicated. The error bars on the chart represent the range of weights collected in each particle size range for the eleven samples. Sieve mesh sizes used for the testing were: ¼ inch, 6, 14, 20, 40, 60, 100, 200, and pan. Lab results for the tests are provided in Appendix K. All of the sampled material had a minimum effective diameter less than ¼ - inch. To facilitate high fuel burn-out in the OGS furnace, the targeted particle sizing was 1/8-inch minus (90 percent of material sized to less than 1/8-inch in diameter).

Exhibit 68 Ground Switchgrass Particle Distribution

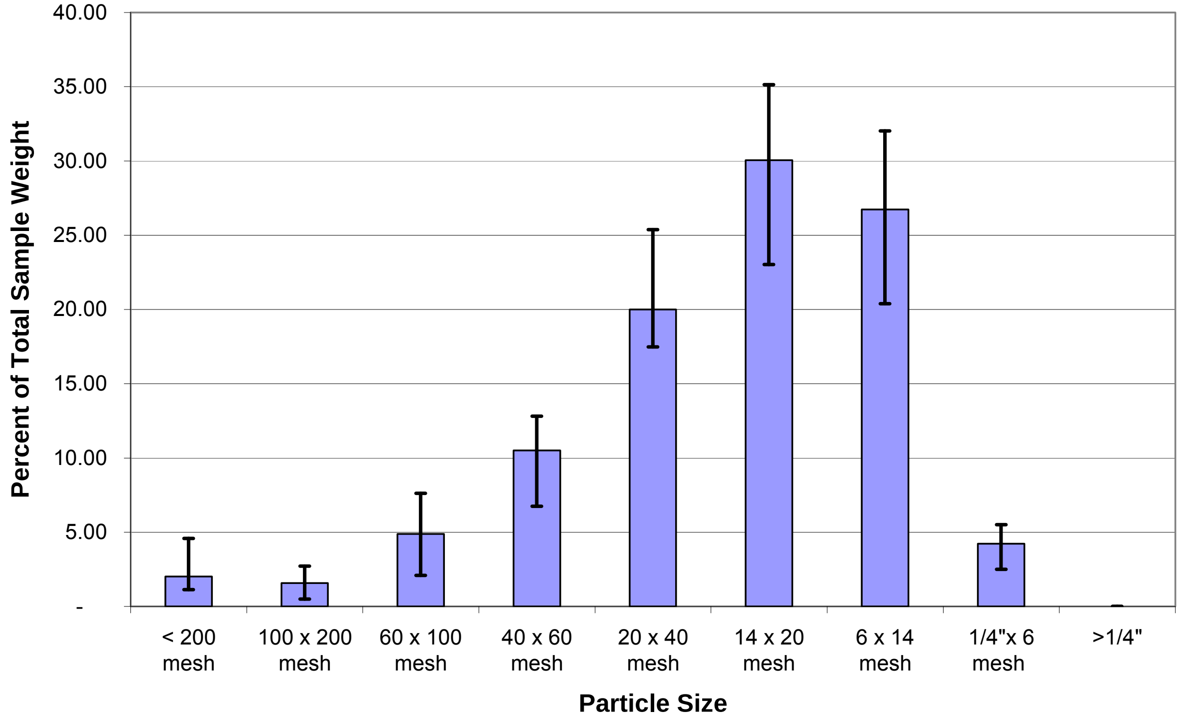
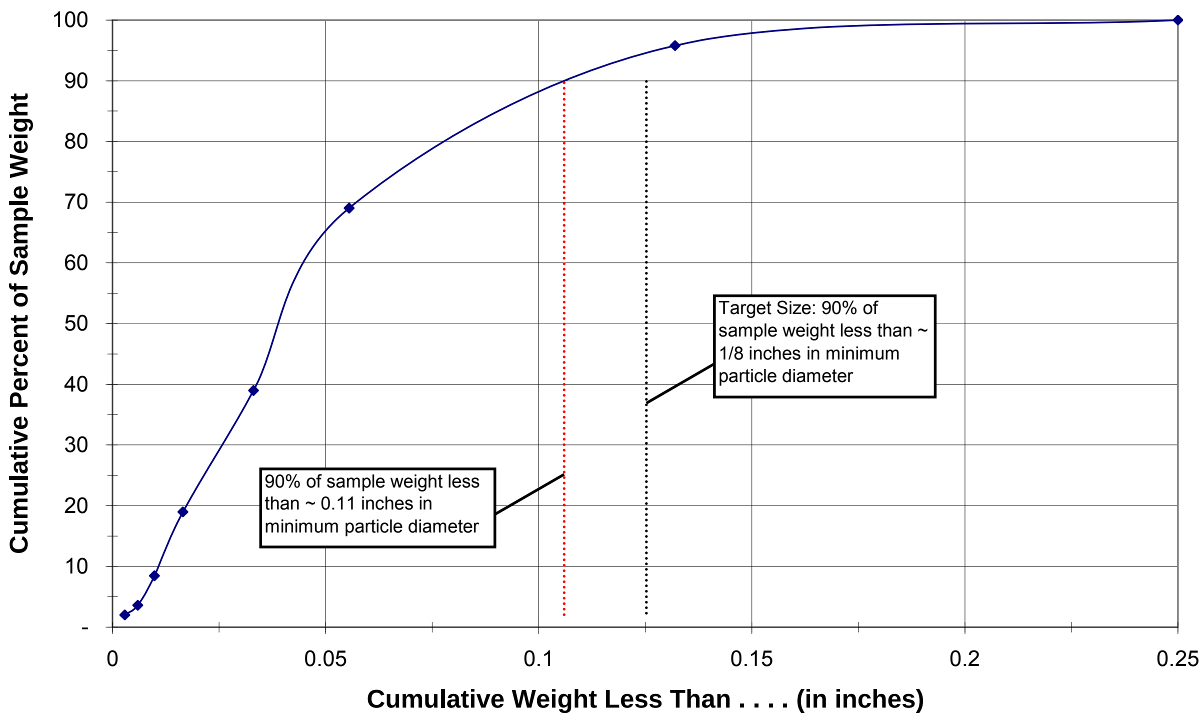


Exhibit 69 Ground Switchgrass Cumulative Particle Sizing



As shown in Exhibit 69, ninety percent of sample weights were sized to less than about 0.11 inches in minimum effective diameter. It should be recognized, as can be observed in Exhibit 64 through Exhibit 66, that the *maximum* length of a significant fraction of the particles exceeded the dimensions graphed in Exhibit 68 and Exhibit 69. The sieve testing measured the minimum effective diameter of those particles (for the longer particles, this was usually the diameter or width of the particle perpendicular to the long particle dimension—the longer particles tended to be very "skinny" or narrow). As used in the discussion above, the minimum effective diameter is the width or diameter of a particle that will allow the particle to pass through the openings in the sieve mesh.

5.3 Biomass Process Facility Power Consumption

Electricity consumption for the biomass processing facility and key pieces of processing equipment was one of the key parameters monitored throughout the Long Term Test Burn. This was monitored to help characterize electricity costs for potential future commercial operations. The information collected can be used to predict future electricity loads of the existing processing facility, and for the existing facility with twice the processing equipment installed according to the original long range plans for the project. As discussed in Chapter 3, current transformers were installed to measure electrical current on both Debaler rotor motors and both "Eliminator" rotor motors. That data was stored on the control room computer for each bale processed throughout the test burn. In addition, for the last half of the test burn a meter was installed on the main electric supply for the facility to monitor overall facility power consumption. Electric demand and power consumption data files were saved on the control room computer for every minute throughout each processing day after April 20th. This section presents the results of the power consumption monitoring throughout the Long Term Test Burn.

5.3.1 Equipment Ratings (hp / kW)

Exhibit 70 and Exhibit 71 summarize the total installed electric loads in the biomass processing facility, by equipment category. The total installed electrical loads amounted to about 1,191 kW. Of that total, 63 percent was for the milling equipment: 38 percent or 447 kW for the "Eliminator" motors, and 25% or 298 kW for the Debaler motors. Blower motors and fans amounted to 20 percent and 6 percent of the total installed load or 242 and 75 kW, respectively. The remaining equipment, including lighting, conveyors, airlocks, and other loads combined for only 11 percent of the installed load. Exhibit 72 lists the horsepower and kW loads for all installed equipment in the facility. Since the facility was designed for processing 12.5 tons per hour, the total installed electrical load per tph (ton per hour) of processing capacity was about 95 kW/tph (1,191 kW / 12.5 tph). Based on the test results, the operational capacity of the facility was about 10 tons per hour on average for the feedstocks tested. So the total installed electrical load per actual ton per hour of processing capability was about 120 kW/tph.

Exhibit 70 Installed Electric Loads for CVBP Processing Facility, by Category

Demand Categories	Total Rated Power (hp)	Max Demand (kW)	% of Total
Conveyors	36	27	2%
Airlocks	24	18	2%
Fans	100	75	6%
Blowers	325	242	20%
Debaler	400	298	25%
Eliminator (Hammermill)	600	447	38%
Lights	n.a.	16	1%
Other *	82	67	6%
TOTALS	**1,567**	**1,191**	**100%**

*** NOTE:** Horsepower totals do not include lighting load or 6 kW electromagnet load. Kilowatt (kW) totals do include those loads.

Exhibit 71 Breakdown of Installed Electric Loads for CVBP Processing Facility

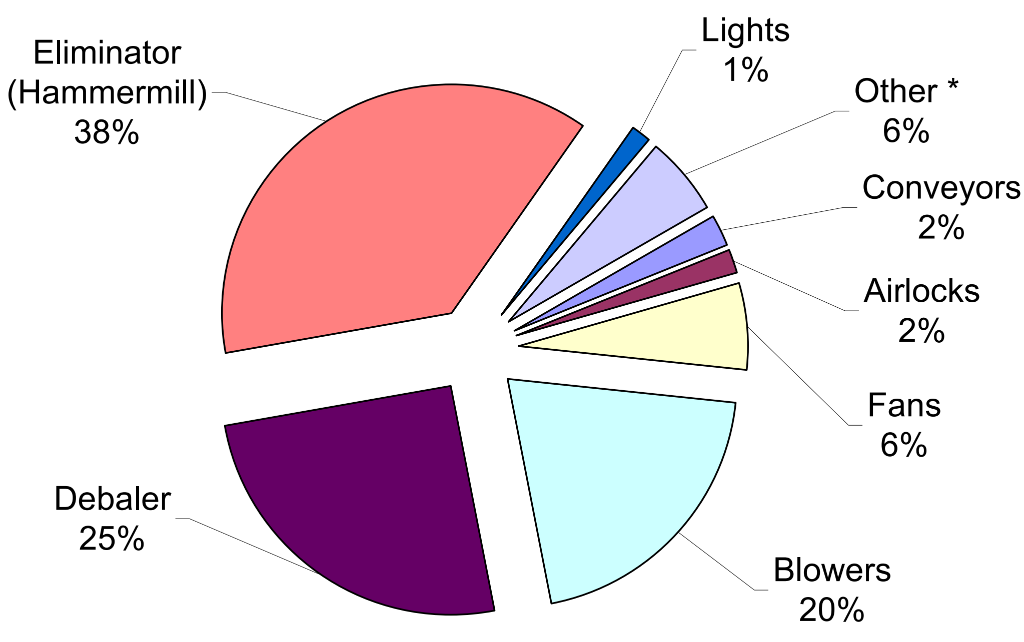


Exhibit 72 List of Installed Electric Loads in CVBP Processing Facility

Equipment	Rated Power (hp)	Max Demand (kW)	% of Total Installed kW
Lighting, High Bay (40 x 400 W)	16 kW	16.0	1.3%
Twin Bale Receiving Conv. (Reversing)	3	2.2	0.2%
Side-Shift Actuator	5	3.7	0.3%
Bale Transport Drive-East (Reversing)	1	0.7	0.1%
Bale Transport Drive-West (Reversing)	1	0.7	0.1%
Surge Transfer 1st Section Drive (Reversing)	1	0.7	0.1%
Bale Kicker (Reject Conv.)	3	2.2	0.2%
Surge Transfer 2nd Section Drive (Reversing)	1	0.7	0.1%
Detwiner I/F Transfer Conv. (Rev. Nord Drive)	1	0.7	0.1%
Detwiner Drive (Detwiner Control Panel)	3	2.2	0.2%
Debaler I/F Transfer Conv. (Nord Drive)	1	0.7	0.1%
Debaler Upper Feeder Motor	200	149.1	12.5%
Debaler Lower Feeder Motor	200	149.1	12.5%
Incline Conveyor to Hammermill	3	2.2	0.2%
Magnetic Belt	3	2.2	0.2%
Magnet (110 VDC)	6 KW	6.0	0.5%
Cyclone To Incline Conveyor Airlock	1	0.7	0.1%
Hammermill Rotor Motor-East	300	223.7	18.8%
Hammermill Rotor Motor-West	300	223.7	18.8%
Baghouse ID Fan	100	74.6	6.3%
Baghouse Separator Blower	25	18.6	1.6%
Baghouse Arm motor	3	2.2	0.2%
Baghouse Rotary Airlock	2	1.5	0.1%
Tubeveyor to Metering Bin	2	1.5	0.1%
Metering Bin Cyclone Airlock	2	1.5	0.1%
Pneumatic System Airlock - East	10	7.5	0.6%
Pneumatic System Airlock - West	10	7.5	0.6%
Metering Bin Screw Drives - East	5	3.7	0.3%
Metering Bin Screw Drives - West	5	3.7	0.3%
Rotary Piston Blower Motor - North	150	111.9	9.4%
Rotary Piston Blower Motor - South	150	111.9	9.4%
Misc. Other (5% of total demand above)	n/a	56.7	4.8%
TOTALS		**1,190.5**	**100%**

5.3.2 Facility-wide Power Consumption

For about the final month of the Long Term Test Burn, a power meter was installed on the main power supply for the biomass processing facility and recorded the facility's total power consumption on a minute-by-minute basis. Exhibit 73 is a chart of the maximum and average electric demand measured (averaged over 5-minute intervals) for each day of testing. Exhibit 74 provides tabulated results along with total daily biomass processed and the average daily power consumption for each ton processed. Maximum daily power demand was typically in the range between 550 and 650 kW while average daily power demand was typically in the range from 450 and 525 kW. The average daily power demand for the period was 477 kW. The maximum electric demand recorded throughout the period was 645 kW (for a 5-minute interval). The maximum daily average power consumption was 521 kW. For the entire period, the average facility-wide power consumption per ton of biomass processed was 49 kWh/ton. The maximum daily average facility-wide power consumption was 58 kWh/ton. Exhibit 75 and Exhibit 76 are examples of facility-wide electric demand profiles over 24-hour periods. Exhibit 75 is for the day when the highest tonnage of biomass was processed. Exhibit 76 is for the final day of the test—processing equipment was shut down at about 5 pm, so power demands beyond that time on May 12th is primarily for facility lighting. Periods when power demands decreased to about 300 kW were times when the Debaler was shut down temporarily to clear out material bridging or to perform maintenance on the Debaler. During processing periods, the electric demand typically varied within a 150 kW range, or about 1/4th of the daily peak.

Exhibit 73 Daily Maximum & Average Power Demands (Entire Facility)

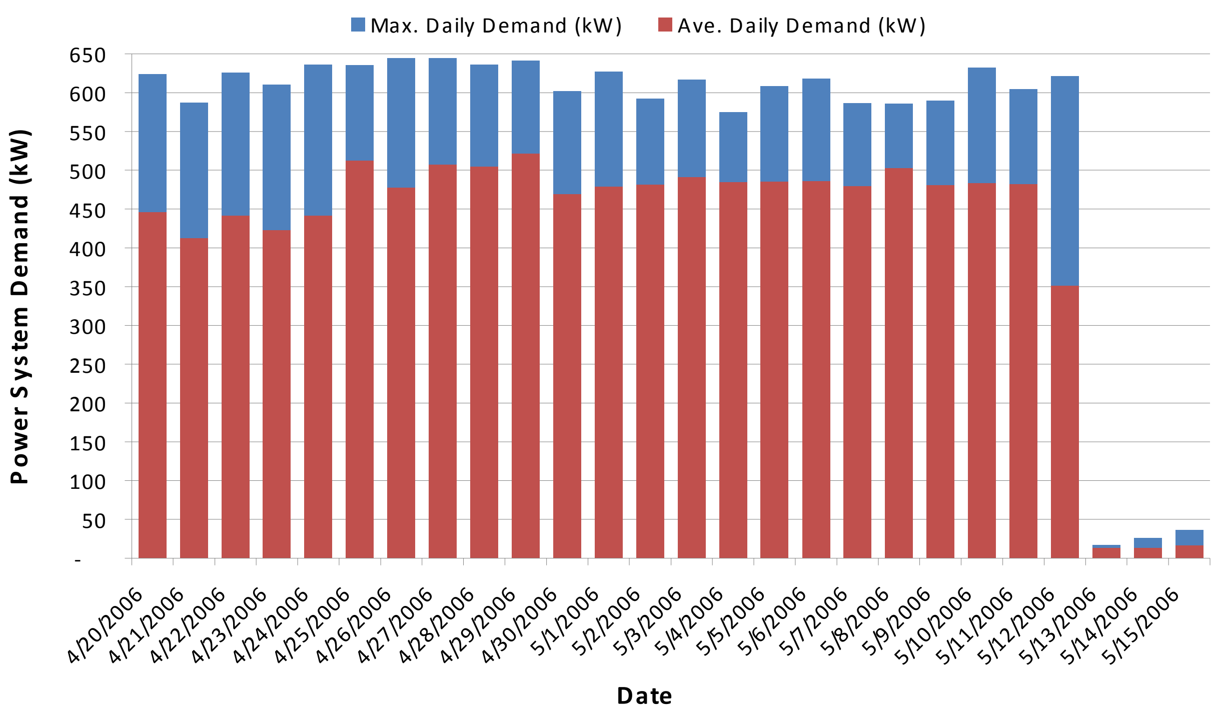


Exhibit 74 Daily Power Demand & Processing Summary Data (Entire Facility)

Date	Power Consumed per day (kWh/day)	Max. Daily Demand (kW)	Ave. Daily Demand (kW)	Min. Daily Demand (kW)	Total Tons Processed	Daily Average Power Consumption Rate (kWh/ton)
4/20/2006	10,701	624	446	29	200	53.5
4/21/2006	9,893	587	412	26	182	54.4
4/22/2006	10,595	626	441	279	182	58.2
4/23/2006	10,126	610	422	26	188	53.9
4/24/2006	10,555	636	441	8	212	49.8
4/25/2006	12,285	635	512	306	262	46.9
4/26/2006	11,479	644	478	25	237	48.4
4/27/2006	12,171	645	507	280	253	48.1
4/28/2006	12,096	636	504	25	251	48.2
4/29/2006	12,490	641	521	295	238	52.4
4/30/2006	11,268	602	469	288	217	51.9
5/1/2006	11,492	627	479	299	220	52.3
5/2/2006	11,556	592	481	243	236	48.9
5/3/2006	11,771	617	491	291	250	47.1
5/4/2006	11,645	575	485	301	265	43.9
5/5/2006	11,613	608	485	240	251	46.2
5/6/2006	11,656	618	486	300	257	45.3
5/7/2006	11,505	586	480	295	258	44.7
5/8/2006	12,057	586	503	292	264	45.6
5/9/2006	11,538	590	481	271	248	46.6
5/10/2006	11,603	632	483	27	255	45.5
5/11/2006	11,512	605	482	94	261	44.1
5/12/2006	8,421	621	351	8	187	45.0
5/13/2006	316	17	13	11	-	n/a
5/14/2006	310	26	13	7	-	n/a
5/15/2006	393	36	16	6	-	n/a
Averages	**11,437**	**615**	**477**	**193**	**236**	**49**
Maximums	**12,490**	**645**	**521**	**306**	**265**	**58**
Minimums	9,893	575	412	8	182	44

NOTE: Average, maximum, and minimum results were estimated considering full processing days only.

Exhibit 75 Daily Electric Demand Profile (Entire Facility, May 4th)

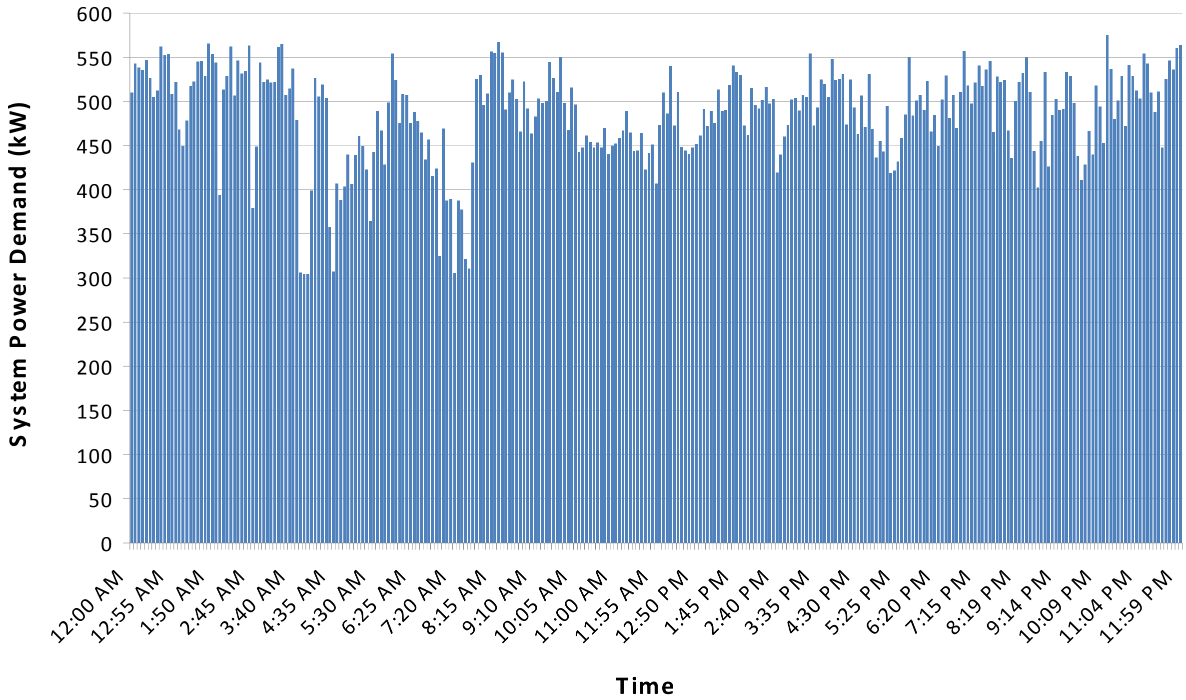
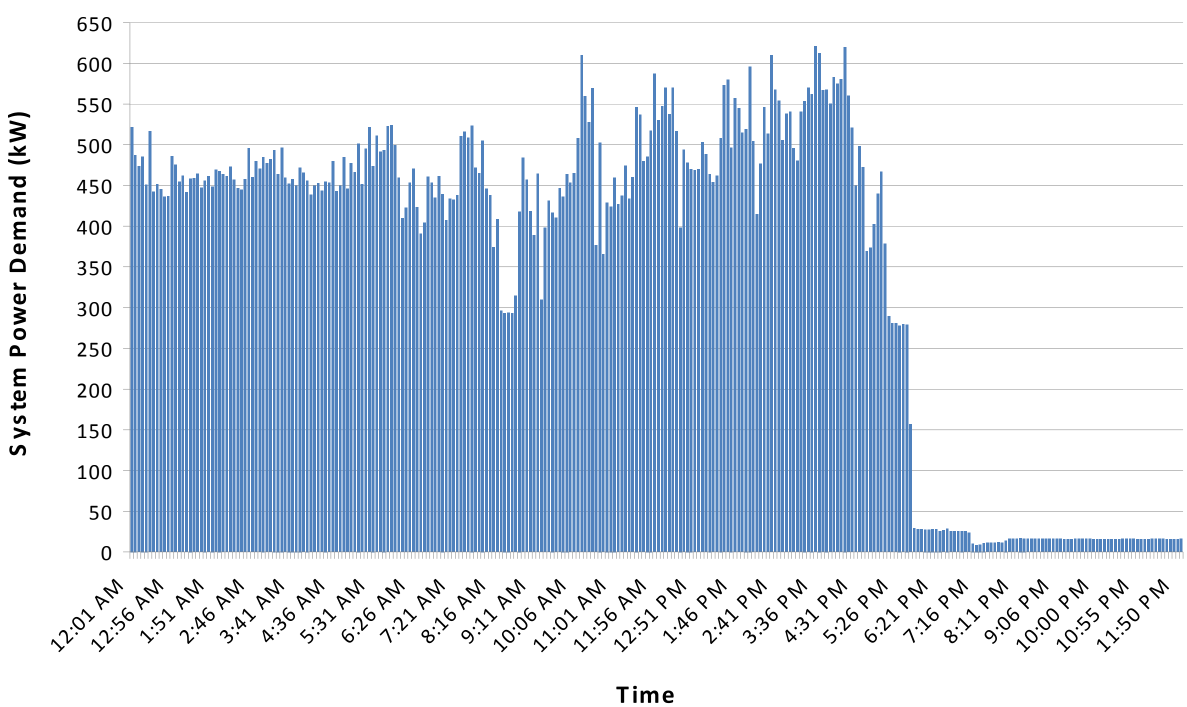


Exhibit 76 Daily Electric Demand Profile (Entire Facility, May 12th)



5.3.3 Milling Equipment Power Consumption

Since such a large fraction of the installed electrical load was for the milling equipment—the Debaler and the "Eliminator"--and since the performance and loading of that equipment significantly effected the biomass processing capacity for the entire processing line, electrical loading on each of those machines was examined in detail. Current transformers were installed on both motors on each machine, and current measurements were recorded for each bale processed throughout the test. Using the current measurements and the supply voltage, power consumption for each machine was calculated. Since moisture content was observed during operations to have a significant impact on process feed rate capability of the system, performance data for periods when bale moisture contents were relatively consistent within a specific moisture content range was analyzed. Each analysis period was typically between 4 and 8 hours in duration. The project team chose lengthy analysis periods with relatively constant bale moisture contents to minimize the uncertainly in the results. Exhibit 77 shows tabulated results for the analysis. A total of about 605 hours of operation were examined, during which 6,281 tons of material was processed. The average power consumption for the Debaler was about 125 kW, or 42 percent of its full load rating. The average power consumption of the "Eliminator" was about 241 kW, or about 54 percent of its full load rating. The average combined measured loads for both machines was about 366 kW, which is about 31 percent of the total facility installed load and about 77 percent of the average operational load for the entire facility.

Exhibit 77 Milling Equipment Power Consumption Versus Moisture Content

Average Moisture Content Range (%)	No. of Data Points[1]	Total Bales	Total Tons	Average Bale Weight (lbs)	Total Analysis Hours	Average Milling Equipment Electrical Load (kW)			Average Milling Power Requirement (kWh/ton) [2]		
						Debaler	Eliminator	Total	Debaler	Eliminator	Total
8.00 - 8.99	2	272	130.2	958	11.0	122.8	247.9	370.7	10.4	21.0	31.3
9.00 - 9.99	5	673	329.0	978	30.3	132.1	240.9	372.9	12.2	22.2	34.4
10.00 - 10.99	16	2,783	1,329.8	956	123.3	126.0	245.9	371.9	11.7	22.8	34.5
11.00 - 11.99	10	1,624	762.2	939	69.0	119.7	253.5	373.2	10.9	23.0	33.8
12.00 - 12.99	7	850	429.5	1,011	41.8	118.7	242.1	360.8	11.6	23.6	35.3
13.00 - 13.99	23	3,030	1,472.2	972	137.0	122.0	241.1	363.2	11.5	22.6	34.1
14.00 - 14.99	11	1,325	679.5	1,026	66.5	123.9	234.5	358.5	12.2	23.0	35.2
15.00 - 15.99	10	982	505.2	1,029	52.5	128.5	232.9	361.4	13.6	24.4	37.9
16.00 - 16.99	5	543	290.8	1,071	31.0	125.5	242.0	367.5	13.4	25.7	39.1
17.00 - 17.99	5	500	258.9	1,035	29.5	149.5	217.2	366.7	17.4	24.8	42.2
18.00 - 18.99	0	--	--	--	-	--	--	--	--	--	--
19.00 - 19.99	2	145	76.1	1,050	11.0	132.1	195.0	327.1	19.2	28.4	47.6
20.00 - 20.99	1	36	17.5	971	2.7	129.0	192.1	321.0	20.0	29.8	49.9
Totals	**97**	**12,763**	**6,281.0**	n.a.	**605.4**	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Weighted Ave.	n.a.	n.a.	n.a.	**984**	n.a.	**125.1**	**240.8**	**365.9**	**12.2**	**23.2**	**35.4**

[1] Data Points correspond to extended periods of processing where switchgrass bale characteristics (ie. Moisture content) remained consistent. These periods generally ranged from 4 to 8 hours in length.

[2] Power ratio only for combination of debaler and eliminator, not for entire facility.

Exhibit 89 is a chart of average electric demand for the Debaler, “Eliminator,” and the combined milling load (Debaler plus “Eliminator”) versus bale moisture content. The dashed bars in the background indicate the tons of material tested within each bale moisture content range, or bin, shown on the x-axis. Power consumption for both machines remained relatively constant at bale moisture contents less than about 16 percent. At higher bale moisture contents, Debaler power remained constant while the power consumption of the “Eliminator” decreased. This indicates that the Debaler was the bottleneck in the process. Operators and the control system would feed bales into the system at the highest rate that the Debaler or “Eliminator” would allow without causing current overloads or material flow problems. At higher moisture contents, the feed rate allowed by the Debaler was low enough that the power consumption for the “Eliminator” decreased.

Exhibit 78 Milling Power Consumption Versus Bale Moisture Content

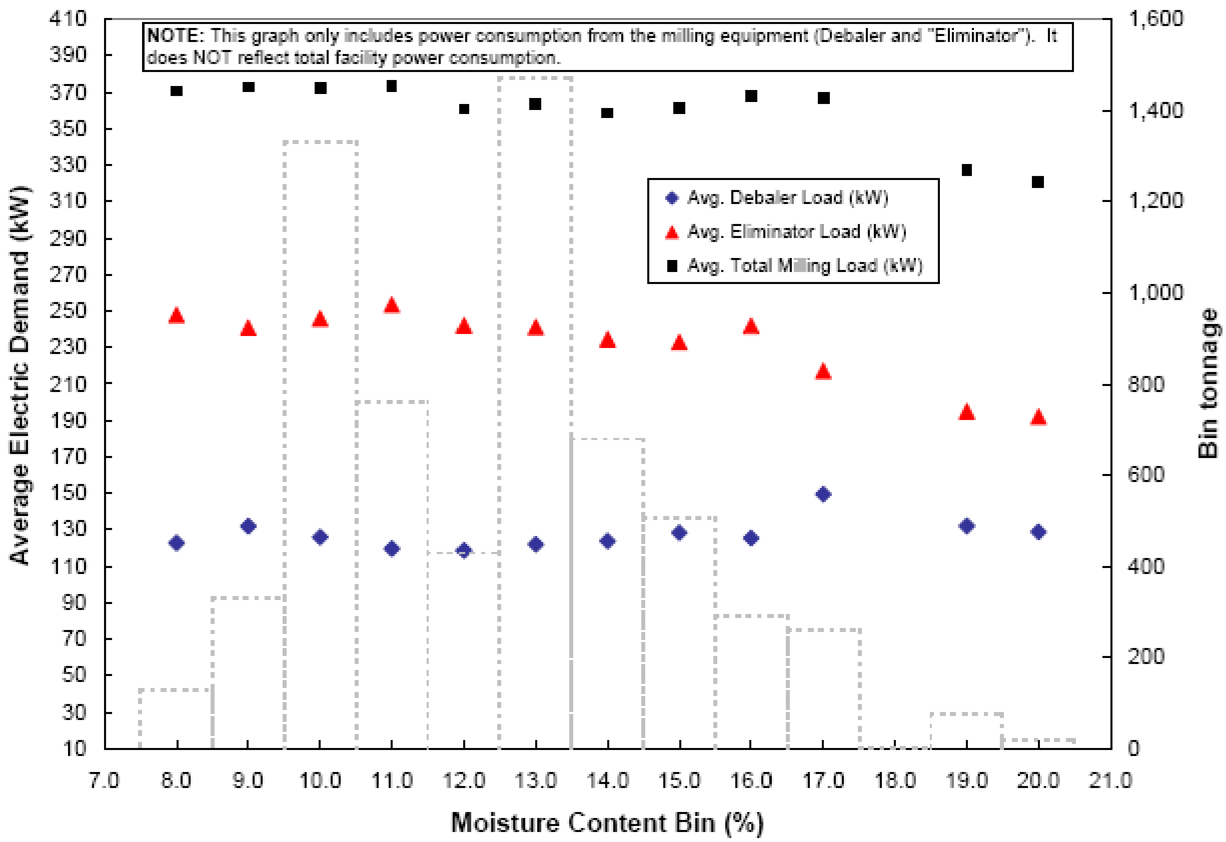


Exhibit 79 shows how the average feed rate through the process line and the combined milling power consumption (on a kWh per ton processed basis) varied as bale moisture content increased. As mentioned previously, as bale moisture content increased, the feed rate of biomass through the system decreased on a nearly linear basis. As a result, the power consumption on a kWh per ton of material processed basis significantly increased as bale moisture content increased. At the low end of the moisture content range (8%), the average feed rate for the system was about 12 tons per hour, while at the high end of the range (20 percent moisture) the feed rate dropped to about 6.4 tons per hour. During the 23 analysis periods examined when the moisture content was relatively consistent and averaged around 13 percent, the average feed rate was 10.7 tons per hour. The milling power consumption rate was relatively constant at around 35 kWh/ton processed up to a moisture content of about 15 percent, and increased significantly for higher moisture contents to 50 kWh per ton for bales averaging 20 percent moisture.

Exhibit 79 Feed Rate and Milling Power Versus Moisture Content

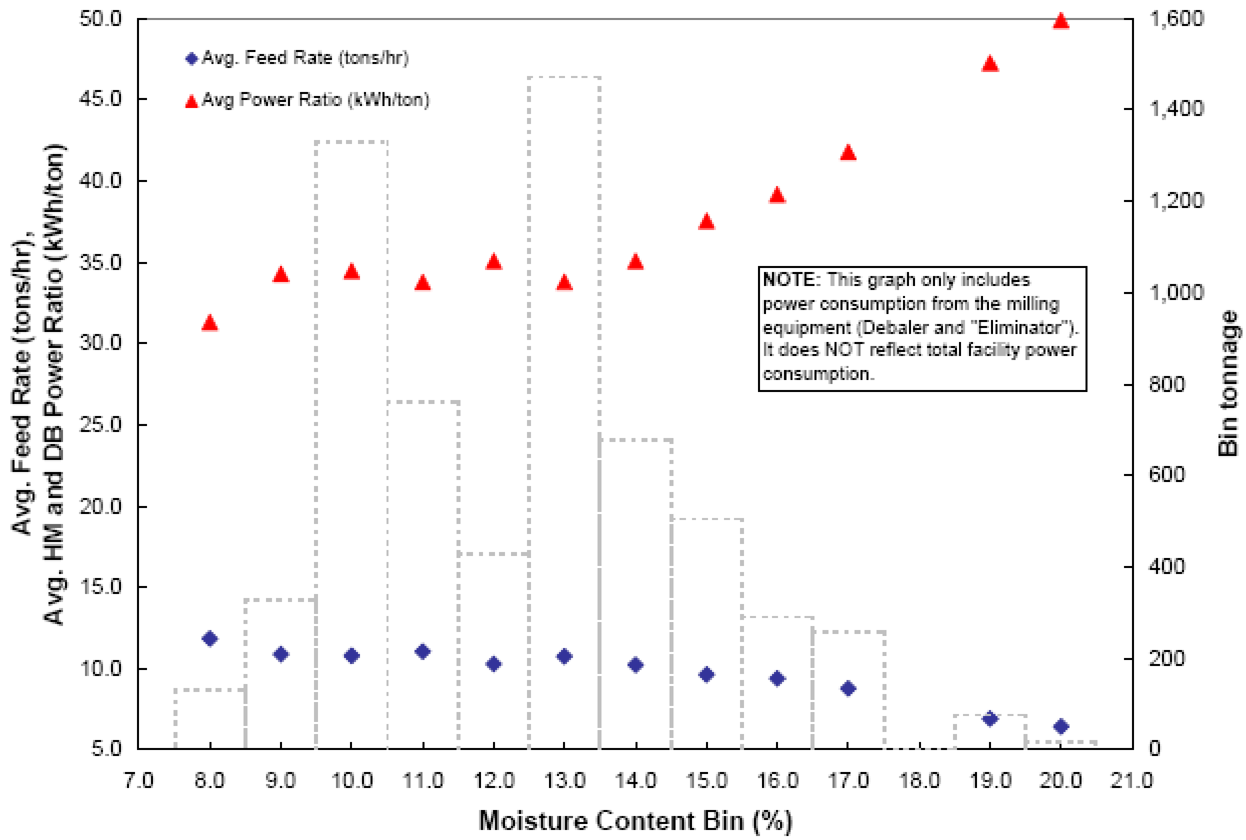
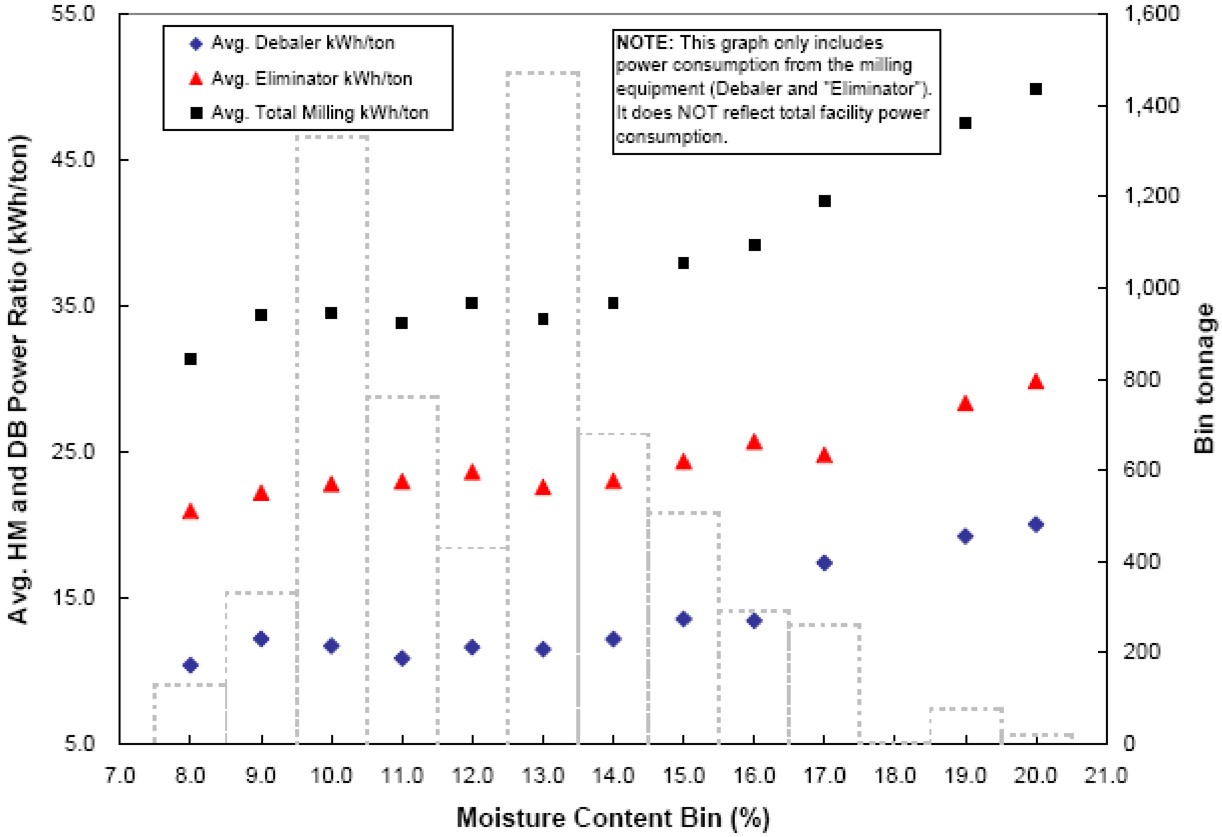


Exhibit 80 shows the impact of bale moisture content on power consumption per ton of material processed for the Debaler, the “Eliminator,” and both machines combined. At the average bale moisture content of 13 percent, the Debaler required an average of about 12 kWh/ton, the “Eliminator” required about 23 kWh/ton, and the combined power consumption rate was about 35 kWh/ton. At the high end of the moisture range, the Debaler power consumption rate was about 20 kWh/ton, the Eliminator required about 30 kWh/ton, and the combined milling power consumption rate was about 50 kWh/ton.

Exhibit 80 Feed Rate and Milling Power Versus Moisture Content



5.3.4 Electricity Costs

The primary reasons for the detailed electricity monitoring described above were twofold: 1) to determine process and control system constraints and performance expectations for the full range of materials tested, and 2) to allow an accurate estimation of electricity use and costs for future commercial operations under various scenarios (full-time operation with one processing line, full-time operation with two processing lines, or part time operational schedules). Prior to the beginning of the test burn, electricity costs were estimated based upon the likely electricity billing schedule from Alliant Energy, the anticipated testing schedule, and the installed capacity of the electrical equipment at the processing facility. The pre-test estimate of total electricity costs was $84,100. The actual billed costs were tracked throughout the test burn period, and the actual billings totaled about $83,200. Monthly electric bills during the full-time test burn months were around $17,000 per month. A table of the electric demand (kW) and usage rates (kWh) that were in effect during the test burn is provided in Exhibit 81. Including demand and usage charges for the test period, the average cost of electricity was about 2.8 cents/kWh during the winter test months in 2006. That rate would have risen to about 4.0 cents/kWh had the testing been performed in the summer months. As discussed further in Chapter 6 and tabulated in Appendix E, all operations and maintenance (O&M) costs were tracked in detail throughout the Long Term Test Burn as an example of what O&M costs might be in a commercially operating project.

Electricity costs were about 13 percent of total costs for operating the biomass processing facility, and were the second highest single cost for operations. Labor costs were the highest cost at 69 percent of the total. Costs tracked included all labor (except administration costs), utilities, insurance, supplies and repair, loader rental, diesel fuel for on-site loaders, land lease, etc.

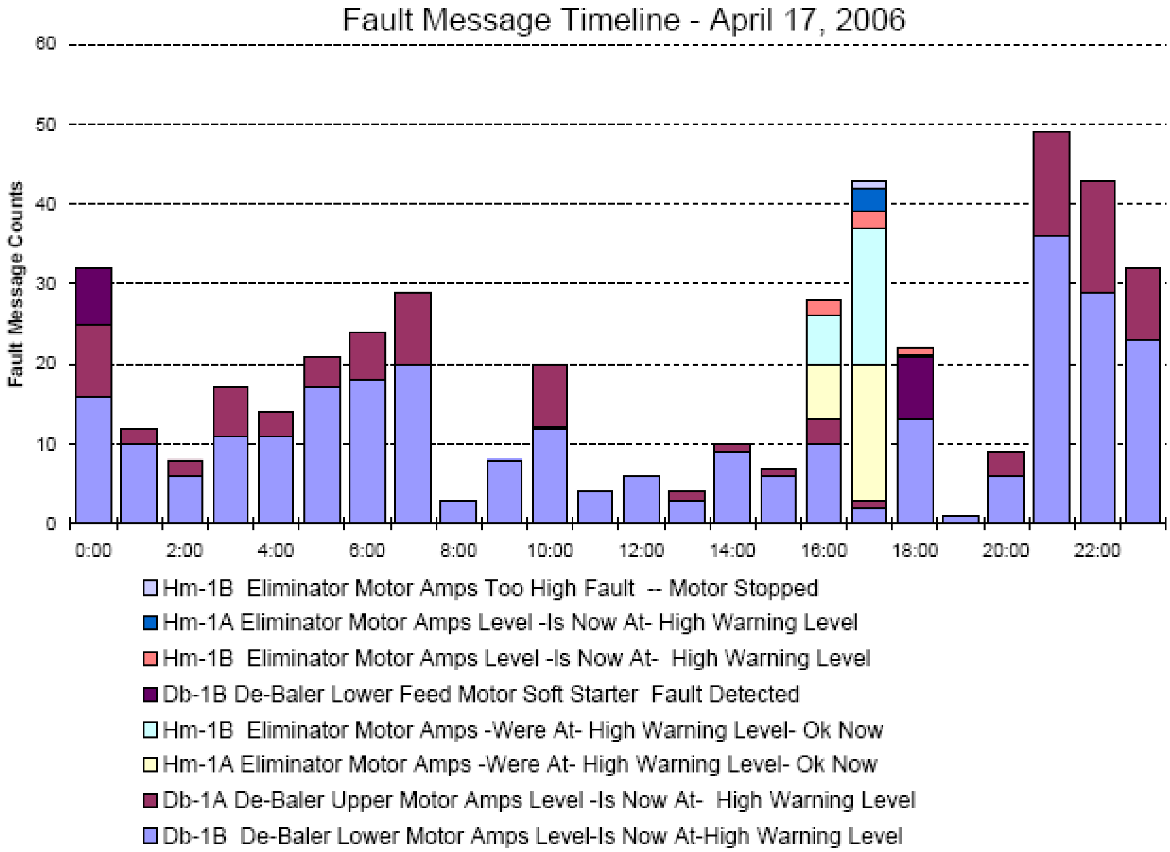
Exhibit 81 Electricity Rates for Demand and Usage, 2006

Monthly Demand Charges ($/kW):	Winter	Summer
First 200 kW	6.75	8.06
Next 800 kW	6.39	7.83
Next 9,000 kW	6.04	7.42
Next 20,000 kW	5.82	6.98
Over 30,000 kW	5.67	6.92
Time-of-Day Option (cents/kWh):		
On Peak kWh	2.510	3.500
Off Peak kWh	1.170	2.120
Non-Time-of-Day Option (cents/kWh)		
All kWh	1.660	2.670

5.4 Biomass Process Facility Fault Message Feedback

The control system for the Biomass Processing Facility was programmed with a list of 240 system fault messages to warn the system operator of potential operational problems, or to indicate reasons for equipment or system shutdowns initiated by the control system. A complete list of the fault messages is provided at the end of Appendix C. When a fault message occurred, a descriptive message box appeared on the control room operator's control screen. Some fault messages were temporary warnings and disappeared automatically when the cause of the fault disappeared—an example of this type of message was a high motor amp warning. Other more serious messages required operator action to clear the message, forcing the operator to acknowledge the message via the touch screen or to resolve the condition that led to the fault message (for example, in the case of a fire alarm notice from the spark detection system in the ductwork between the "Eliminator" and the baghouse). In most instances, this system was very effective in notifying system operators about potential operational problems early on before serious equipment-related problems occurred. Under normal operational circumstances, high motor amp warnings for the Debaler motors were by far the most frequent fault messages (particularly for the lower Debaler motor). The time and description for each fault message generated by the control system was automatically saved in a data file for each day of operation. Exhibit 82 and Exhibit 83 show graphed counts of fault message indications for two example days on an hour-by-hour basis. Additional daily examples are included at the end of Appendix C.

Exhibit 82 Fault Message Timeline Example, April 17, 2006



While the fault messaging system that was employed during the test burn was extremely helpful for diagnosing immediate problems and operational issues, improvements could potentially be made to the system. With modest software changes or additions, the system could be designed to be used in a more predictive fashion as an early indicator of developing conditions that, if left unattended, could lead to significant equipment failures and extended downtime for repairs. An example of such a circumstance is shown in Exhibit 84. As mentioned previously, one of the rotor shafts on the Eliminator fractured and failed on March 26th. The frequency of occurrence of fault messages relating to the "Eliminator" was examined for the five days prior to the failure and the five days following the failure. Exhibit 84 shows the results. For the five days prior to failure, a total of 1,805 fault messages occurred and all of the messages related to high amp measurements on the "Eliminator" motors. Upon failure of the rotor shaft, it was observed that the hammers in the "Eliminator" were highly worn. During the downtime to repair the rotor shaft, new hammers were also installed. On the five days following the failure, only 80 fault messages occurred relating to the "Eliminator." There was not a significant difference in the types of material or moisture content in the bales processed during this 10 day period. In the future, daily reports of fault frequencies (and changes versus norms) for each piece of equipment in the process system could provide early warning of pending failures in time to allow operators to initiate maintenance and repairs in a more controlled and less costly manner.

Exhibit 83 Fault Message Timeline Example, April 18, 2006

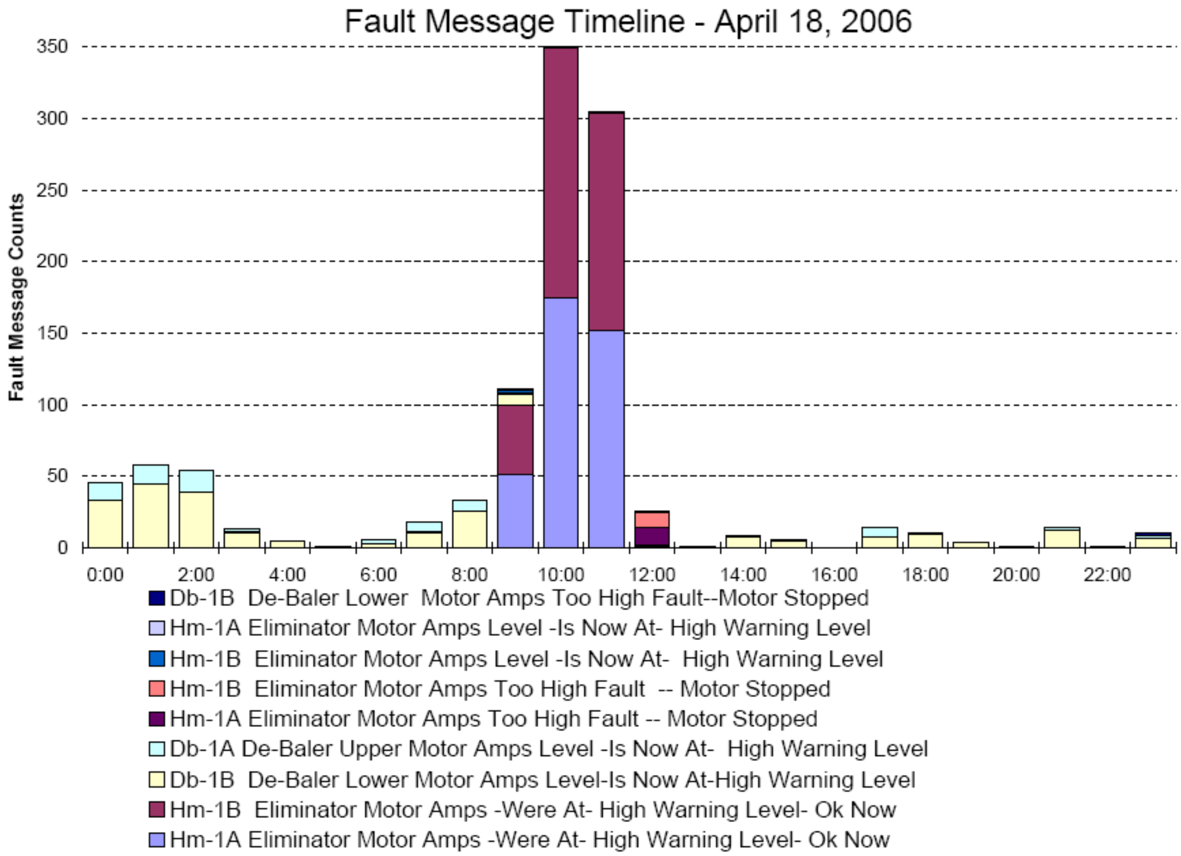


Exhibit 84 Fault Messages Before and After Hammermill Rotor Failure

Fault #	Fault Message	Counts - 5 Day Period Before Rotor Replacement	Counts - 5 Day Period After Rotor Replacement
	HAMMERMILL RELATED FAULTS		
108	HM-1A ELIMINATOR MOTOR AMPS LEVEL -IS NOW AT HIGH WARNING LEVEL	179	4
109	HM-1A ELIMINATOR MOTOR AMPS -WERE AT- HIGH WARNING LEVEL- OK NOW	759	11
110	HM-1A ELIMINATOR MOTOR AMPS TOO HIGH FAULT - MOTOR STOPPED	6	22
115	HM-1B ELIMINATOR H-MILL SOFT STARTER FAULT DETECTED	0	0
116	HM-1B ELIMINATOR MOTOR AMPS LEVEL -IS NOW AT- HIGH WARNING LEVEL	215	9
117	HM-1B ELIMINATOR MOTOR AMPS -WERE AT- HIGH WARNING LEVEL- OK NOW	637	12
118	HM-1B ELIMINATOR MOTOR AMPS TOO HIGH FAULT -- MOTOR STOPPED	9	22
Total		**1,805**	**80**

5.5 Key Factors Impacting Biomass Processing Capacity

Throughout the Long Term Test Burn, several key factors affecting the processing system's ability to process biomass at higher rates were identified, and where possible, quantified. In estimated order of impact on reducing production rates, the key factors were:

- High bale moisture content
- High content of certain foreign species, such as foxtail, in bales
- Poorly formed or packaged bales
- Increased wear on hammers and screens in the Debaler and "Eliminator"

This section briefly discusses each of these factors and, where possible, potential means of reducing the negative impact of each of these factors on facility production rates. The potential impacts of these factors on production economics is also discussed were possible.

5.5.1 Moisture Content

The impact of increased bale moisture content on process power consumption and feed rates is discussed in detail in Section 5.4 and is graphed in Exhibit 77.
Exhibit 85 provides tabulated results. At the low end of the moisture content range (8%), the average feed rate for the system was about 12 tons per hour, while at the high end of the range (20 percent moisture) the feed rate dropped by nearly half to about 6.4 tons per hour. At the average bale moisture content of about 13 percent, the average feed rate was 10.7 tons per hour during the analysis period. As discussed later in this section, the reduced feed rates at higher moisture content can have a dramatic impact on production economics due to the fact that the same facility operating costs are being spread across significantly reduced processed feedstock tonnage within a given period of time.

The impact of moisture content on production rates at this facility could be reduced by taking one or more of the following actions:

- Replacing the existing 200 hp Debaler motors with 250 hp motors. The existing rotors were designed for 250 hp motors and should be able to handle the increased loading. This will reduce the frequency of process feed delays due to high amp levels on the Debaler motors, and would result in at least modest feed overall rate improvements.
- Install a second debaling line and potentially a second hammermill or replacement hammermill with a higher process capacity on high moisture material. This would provide process redundancy during periods when processing dry material, and additional process capacity to allow the system to meet a 12.5 ton per hour feed rate when processing wet material.
- Minimize moisture content of incoming bales by screening bales and removing high moisture content bales when loading trucks for delivery to the plant.

- Minimize moisture content of stored bales by reducing exposure to water during storage (in particular in some of the storage buildings, bales stored on the bottom of the piles were exposed to periodic standing water/puddles).
- Evaluating alternative equipment for debaling or second-stage milling. It is possible that other equipment exists that will be less sensitive to increased moisture.

Exhibit 85 Impact of Bale Moisture on Process Feed Rate & Milling Power

Avg. Moisture Content Range (%)	# Data Points[1]	Total Bales	Total Tons	Average Bale Weight (lbs)	Average Feed Rate (tons/hr)[2]	Average Power Ratio (kWh/ton)[3]
8.00 - 8.99	2	272	130.2	958	11.8	31.3
9.00 - 9.99	5	673	329.0	978	10.9	34.3
10.00 - 10.99	16	2783	1329.8	956	10.8	34.5
11.00 - 11.99	10	1624	762.2	939	11.0	33.8
12.00 - 12.99	7	850	429.5	1,011	10.3	35.1
13.00 - 13.99	23	3030	1472.2	972	10.7	33.8
14.00 - 14.99	11	1325	679.5	1,026	10.2	35.1
15.00 - 15.99	10	982	505.2	1,029	9.6	37.5
16.00 - 16.99	5	543	290.8	1,071	9.4	39.2
17.00 - 17.99	5	500	258.9	1,035	8.8	41.8
18.00 - 18.99	0	--	--	--	--	--
19.00 - 19.99	2	145	76.1	1,050	6.9	47.3
20.00 - 20.99	1	36	17.5	971	6.4	49.9

[1] Data Points correspond to extended periods of processing where switchgrass bale characteristics (ie. Moisture content) remained consistent. These periods generall ranged from 4 to 8 hours in length.

[2] Overall average feed rate: total tons processed divided by hours

[3] Power ratio only for combination of debaler and eliminator

5.5.2 Foreign Material in Bales

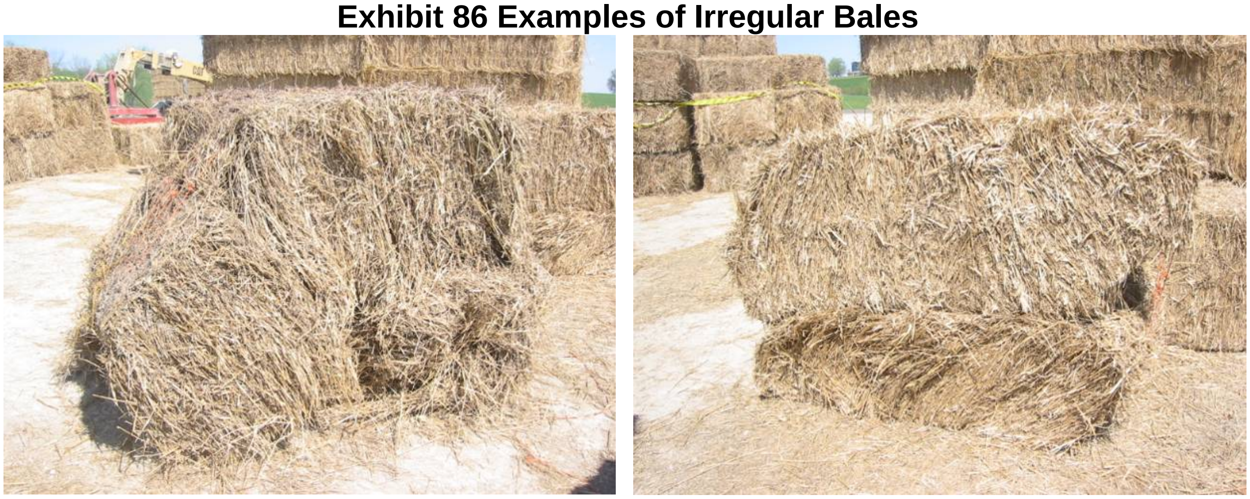
Although the large majority of material included in the processed bales was switchgrass, depending on the conditions in the field (the amount of weed species in the field), some bales included relatively high levels of foreign material. The two primary types of foreign species observed were: 1) slender foxtail grasses, and 2) “woody” weeds such as Goldenrod (when dry, this material looked like small-diameter stalks of wood with a soft core). The “woody” material processed relatively easily, and bales containing high quantities of this material were typically low in moisture content. When processed, this material tended to be finer than other tested materials, including switchgrass. Photos of this type of material, after debaling and second-stage hammer milling, are shown in Exhibit 66. Because of its tendency to be dry and also more brittle, this “woody” material could be processed at equal or high rates compared to switchgrass and other materials encountered during the tests. The bales containing high foxtail content were the most difficult material encountered during the testing. Those bales tended to be higher on average in moisture content, and the stringy nature of the foxtail seemed to be more difficult to mill. Those bales required more power to mill, and the processed material was bulkier than the other materials and was therefore more prone to cause plugging and other flow problems. Photos of processed material with a high foxtail content are shown in Exhibit 65.

The primary way to reduce foreign material in bales would be to implement best practices for crop establishment and maintenance throughout the harvest fields, thereby reducing the weed content in the harvested fields. Quality control could also be implemented at the biomass processing facility or during bale screening at the storage facilities. Bales with high undesirable foreign material content could be rejected for acceptance at the processing facility of for hauling at the storage facilities. The ideal situation would be to obtain approval to burn a wide range of materials that will be encountered in the local area and throughout the year, and to have a processing system that is either less sensitive to material variations or oversized enough to be able to provide the targeted processing rate for the worst possible material expected.

5.5.3 Bale Quality

Another factor that reduced the efficiency and processing rate of operations at the biomass processing facility, both during truck unloading operations and on the process line, was receipt of irregular bales that were misshaped or poorly packaged such as those shown in Exhibit 86. Handling these bales required extra attention and time.

Exhibit 86 Examples of Irregular Bales

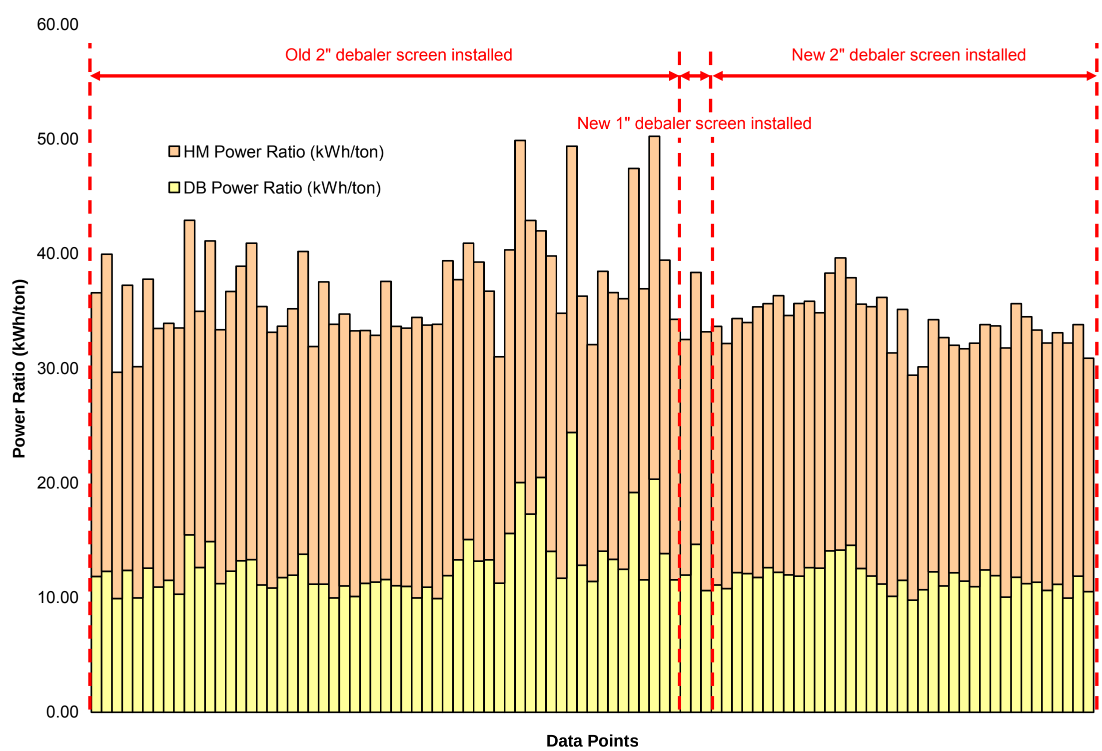


If misshaped or poorly packaged bales were loaded onto the process line, operators typically had significant trouble and often had to stop the conveyor system to remove the problem bales. Early on in the Long Term Test Burn, operators decided to sort out irregular bales that were hauled to the processing facility to keep them from being loaded into the process line. During a commercially operating project, irregular bales should either be sorted out prior to hauling (this practice was also implemented during the Long Term Test Burn) or a small process line more suitable for handling that type of material could be added to the processing system. Facility operators would have to make a determination as to whether the volume of irregular bales or the value of processing them warrants the added expense for the additional processing equipment.

5.5.4 Screen and Hammer Wear in Milling Equipment

Excessive debaler screen and "Eliminator" hammer wear were both encountered at different times during the Long Term Test Burn. In the case of the worn debaler screens, operators noticed an increased frequency of high amp warning messages for the debaler motors from the control system. Operators also noticed increased difficulty in maintaining targeted process feed rates (also likely due to the increased motor currents for the debaler motors). Operators shut the system down to inspect the debaler screens and noticed significant wear, so the worn screens were replaced with new screens. As a test, and while new 2-inch screens were being delivered, the screens were initially replaced with 1-inch screens. After several days of operating with 1-inch screens, new 2-inch screens were delivered and installed. Exhibit 87 and Exhibit 88 show "Eliminator" (HM) and Debaler (DB) power ratios (kWh/ton) before and after

Exhibit 87 Effect of Debaler Screen Changes on Power Ratio

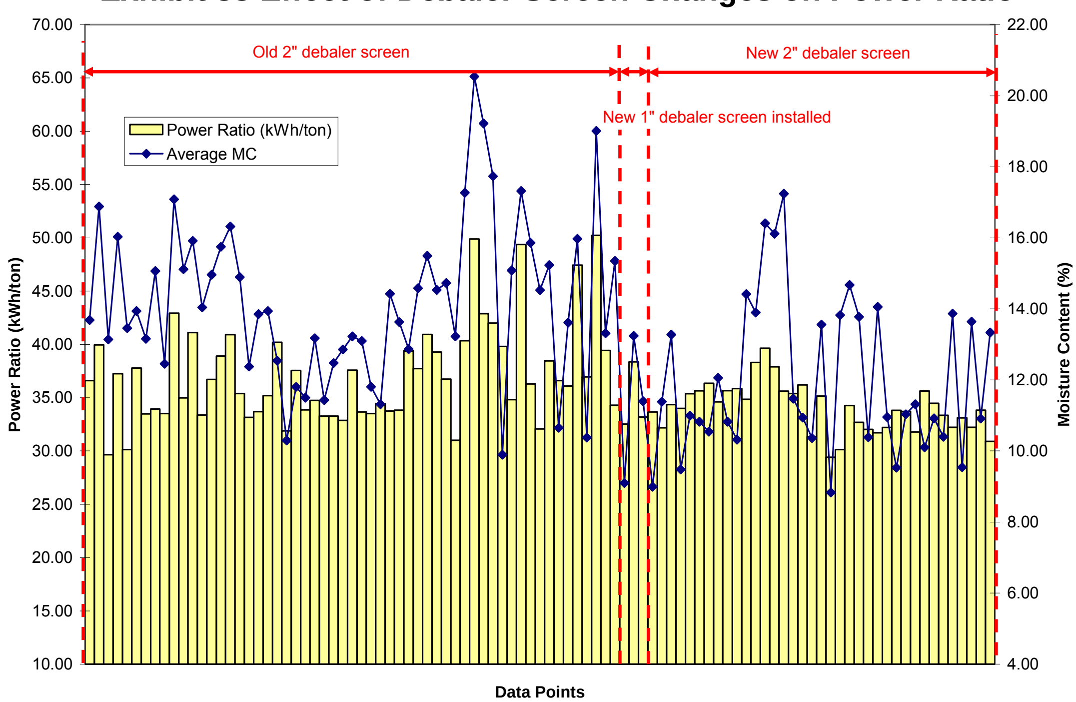


the screen changes. Exhibit 88 also includes a daily average bale moisture content line. The exhibits demonstrate the improved performance of the debaler, independent of bale moisture content variations. In the days preceding the screen changes, power consumption ratios (kWh/ton) were significantly higher than after the changes.

As discussed previously in this chapter and shown in Exhibit 84, similar behavior also occurred due to excessive wear on the hammers in the "Eliminator." To minimize the extent to which these conditions negatively impact processing performance, the following recommendations should be followed:

- Power consumption (amp levels) trends should be monitored closely for all mill motors (Debaler and "Eliminator"), and screens or hammers should be checked when the number of high amp warning messages increases significantly over process norms, or when feed rates or calculated kWh/ton figures begin to consistently differ from establish norms. This could be accomplished using automated daily reporting either within the control system's software, or using an external software package.
- Hammers and screens should be fabricated using harder materials and with thicknesses or other attributes intended to reduce the time between required replacement, as discussed in Chapter 4.
- The spares inventory should contain ample quantities of hammers and screens to allow immediate and complete replacements for all parts subject to wear, for the Debaler and the hammer mill. (Due to budget constraints during the test burn, the spares inventory was minimized to those items expected to need replacement during the test period. Some parts wore faster than expected.)

Exhibit 88 Effect of Debaler Screen Changes on Power Ratio



5.5.5 Results from Bale Batch Testing

Due primarily to the abbreviated length of the first two test burns, fairly consistent and high quality bales were tested throughout the duration of those tests. During the Long Term Test Burn, a much wider variety of bales was encountered. These bales had been collected over a period of years, on a wide range of fields, and by different types of harvesting equipment. Some of the bales were from recent harvest activities, and others had been stored for several years. Early on during the Long Term Test Burn, the project team noticed that problems were occurring when bales were irregular, inconsistent, or had high moisture content or high foxtail content. To better understand how different types of bales affected the processing system, a series of batch tests were performed during the test burn. The goal of the batch testing efforts was to quantify the added costs and reduced running time caused by problem bales. With this information, a quality control formula could be developed for grading and valuing bales delivered to the processing facility in a future commercial operation. Or, at a minimum, measured results could be used to make decisions about what types of bales to discourage or reject, and what types of practices to try to implement in the field to foster production of bales during harvest that processed well at the processing facility.

The batch testing was conducted from April 20 to 21. Six types of bales were tested, with three batches processed on each day:

- Batch #1: High switchgrass content, low moisture bales (reference batch)
- Batch #2: High switchgrass content, high moisture bales
- Batch #3: High foxtail content bales
- Batch #4: Loosely packaged bales
- Batch #5: High woody weed content bales—these bales contained noticeably higher content of weed species such as goldenrod, horseweed, ragweed, hemp, thistles, etc.
- Batch #6: Bottom bales—these bales were stored on the bottom of the stacks in the storage buildings and were therefore more prone to have damaged shape, added moisture on the bottom side, and additional dirt, mold, and/or discoloration (they were black in some places).

Approximately 30 to 50 bales in each of these categories were grouped together at the remote storage facilities and at the processing facility. High moisture content bales were separated from low moisture content bales by probing the bales with a hand-held hay probe. Each group of bales was hauled to the processing facility and sent through the processing system separately (in batches) in order to monitor the continued impacts on power consumption, feed rate, and down-time for the processing system. To remove operator skills and preferences as a variable from the testing, the same lead operator ran the processing system throughout the testing for all six batches. The test results are presented in Exhibit 89.

The reference case (Batch #1) results showed that processing bales with high switchgrass content and low moisture consumed around 46 kWh per ton (for the entire facility electrical use), and had a feed rate of 11.4 tons per hour. Batch #1 was chosen as the reference batch for comparing to the other batches since this was the desired targeted feedstock for the test. Bales with high moisture and high foxtail (also high in moisture) content were the most difficult to process, causing measured increases in power consumption, decreases in average feed rate, and increased downtime. Loosely packaged bales also resulted in increased downtime; however, those bales were also very low in moisture content and processed very well once they reached the debaler (likely due to the fact that the debaler motor amp surges were less severe with these less densely packaged bales as compared to the more dense, tighter packaged bales). From a performance perspective, Batch #5 (High woody weed content bales) was the easiest to process even though the average moisture content of that batch was higher than that for Batches #1 and #4.

It should be noted that although no downtime is shown for the bottom bale batch (Batch #6), the lead operator had to come out of the control room to go down onto the floor level 18 times in less than two hours to help resolve mechanical issues with bale feeding and de-stringing. That is obviously not a desirable rate of maintenance or required attention from the lead operator. For bales similar to Batch #1, the lead operator indicated that he could typically set the bale infeed variable frequency drive (VFD) at 40% of the maximum feed rate, or to about 4.3 ft per second on the Debaler infeed conveyor, and amps on the “Eliminator” would become the limiting factor for the process feed rate. For bales similar to those in Batches #2 and #3, the lead operator typically had to set the Debaler infeed conveyor VFD at 15% of the maximum feed rate and high Debaler motor amps would still be the limiting factor on the process feed rate. Current swings would regularly range from about 80 to over 400 Amps when processing these types of bales, especially those with high foxtail content.

Comparisons of estimated increased processing costs, on a $/ton basis, were made between the reference batch (#1) and each other batch for both electricity costs and reduced feed rate costs. Those results are shown near the bottom of Exhibit 89. Increased electricity costs were estimated assuming an average electricity cost of about 6.5 cents/kWh (a conservative number) and the electricity usage rates measured during the tests. Batches #2 and #3 required about $0.65 and $1.11 per ton in additional electricity costs compared to Batch #1, respectively. Batches #4 through #6 required either the same or slightly less electricity costs. The impact of reduced feed rate was far more significant. Using an estimated $20 per ton as the nominal facility operating cost (based on overall average costs for the last two months of the test burn period), the differences in total facility operating costs were estimated for each batch compared to the reference batch. With lower feed rates and increased downtime, it requires more processing hours and operating costs to process the same tonnage. Batches #2 and #3 required about $9 and $12 per ton, respectively, more to process due to reduced feed rates compared to Batch #1. Batches #4 through #6 were comparable in overall cost. If the reduced hourly revenue from the total enterprise (payments for delivered bales, plus payments for processing services) is considered in the assessment instead of just the processing expenses, the added costs for the reduced feed rates get significantly steeper. That cost would either have to be absorbed within the biomass supply operations, or passed along to the buyer.

Exhibit 89 Summary Table for Bale Batch Processing Tests

Test Parameter	Batch 1 (High Switchgrass, Low Moisture)	Batch 2 (High Switchgrass, High Moisture)	Batch 3 (High Foxtail Content)	Batch 4 (Loosely Packaged Bales)	Batch 5 (High Woody Weed Content)	Batch 6 (Bottom Bales)
Testing Period	10:33 AM - 12:41 PM	12:43 PM - 4:10 PM	4:25 PM - 7:48 PM	11:00 AM - 12:32 PM	12:35 PM - 1:56 PM	1:58 PM - 3:42 PM
Total Test Time [1] (hours)	2.1	3.5	3.4	1.5	1.4	1.7
Run Time (hours)	2.1	2.5	3.0	1.1	1.4	1.7
Down Time (hours)	0.0	0.6	0.4	0.4	0.0	0.0
Bales Processed	50	46	45	38	39	39
Tons Processed	24.3	24.6	24	17.2	17.5	18.9
Ave. Weight (lbs)	1,152	1,068	1,068	903	899	969
Ave Moisture (%)	9%	16%	17%	9%	12%	14%
Moisture Range	5% - 18%	12% - 22%	7% - 25%	5% - 14%	7% - 15%	0% - 20%
Ave. Run Time Feed Rate (tons/hr)	11.4	9.8	8.0	15.6	12.5	11.1
Ave. Overall Feed Rate (tons/hr)	11.4	7.9	7.1	11.5	12.5	11.1
Power Consumption, Entire Facility (kWh)	1,127	1,377	1,521	793	737	830
Power Consumption, Entire Facility (kWh/ton)	46	56	63	46	42	44
Electricity Premium ($/ton) [2]	Batch 1 was used as the comparative baseline for these parameters for subsequent batches. [4]	**$0.65**	**$1.11**	**$0.00**	**($0.26)**	**($0.13)**
Reduced Feed Rate (tons/hr)		3.5	4.3	(0.1)	(1.1)	0.3
Reduced Feed Rate Cost ($/hr) [3]		$69	$86	($2)	($22)	$5
Reduced Feed Rate Premium ($/ton)		**$8.71**	**$12.12**	**($0.13)**	**($1.78)**	**$0.49**

NOTES:

1) Total test period times do not necessarily equal the sum of tabulated run times and down times. If a downtime occurred that was not attributable to the bale types (such as a spark detection system trip), that time was not considered as downtime for this analysis.

2) Assuming 0.065 $/kWh electricity rate.

3) Assuming a nominal cost of $20/ton for processing bales.

4) All comparisons are done relative to Batch # 1.

5.5.6 Developing a Quality Control Formula

As demonstrated above, the cost of delivering bales with elevated moisture content, increased undesirable foreign species, or other problematic attributes (packaging, sizing, etc.) can be quantified and significant (increasing costs by $9 to $12 per ton for some of the conditions tested and discussed above). To help encourage and incentivize delivery of higher quality bales to the processing facility, a grading and valuing strategy could be developed using a process similar to that described above to establish a base value for acceptable delivered bales. Incentives above the base could be offered for deliveries that correspond with improved operating conditions at the processing facility. At a minimum, a valuation system including bale content (type of material within the bale) and moisture content should be considered and would be fairly easy to implement from an operations perspective. The processing facility control system already has the capability to weigh and calculate average moisture content corresponding to a specific truckload (as long as all bales from the truckload are processed at once). The control room operator can enter a truckload number into the control system and bale weights and moisture contents will be recorded for that truckload. The same could also be done during delivery if truck scales with moisture content sensors were installed. A subjective grade based on the appearance of the bales could be made regarding bale content during the unloading process, or the control room operator could make that determination based upon measured reduced feed rates for a particular load. That information could be recorded along with each truckload's tonnage and moisture information and linked to delivery payments. If pursued, the grading system would have to consider to what extent a supplier could reasonably control the factors considered in the grading process (primarily moisture).

5.6 Air Emissions Impacts

Over the course of its history, this project conducted three test burns at Ottumwa Generating Station (OGS). Each test burn had different objectives as summarized in Chapter 2. Each of the tests involved collection and analysis of air emissions data, with varying levels of detail and emphasis on air emissions issues during each test. The first test burn was primarily a proof-of-concept test to demonstrate that switchgrass could be burned in the OGS boiler without causing significant short-term problems to plant operations and air emissions. Detailed collection and documentation of air emissions data was secondary during that test to running the biomass processing equipment and attempting to keep the system operating in a steady manner. Of the three test burns, the second or Interim Test Burn was most focused on detailed collection and documentation of air emissions data since that test was as the basis for air permit applications. The test protocols and plan were carefully coordinated with the Iowa Department of Natural Resources to ensure that the test yielded the information they expected and needed for permitting and environmental evaluation purposes. The third and final test, the Long Term Test Burn (LTB), was primarily aimed at operating the newly installed biomass processing facility on a pre-commercial continuous basis for a targeted 2,000 continuous hours. The targeted duration of the test was to provide enough continuous burn hours to allow an evaluation of potential long-term impacts such as fouling, slagging, and corrosion on the boiler and plant equipment. This test was designed to build enough confidence in the biomass processing system and plant operations while cofiring to allow the businesses involved to make a sound decision about the prospects for commercial operation. Air emissions were monitored throughout the LTB and differences during cofiring and coal-only periods were compared using data from the plant's Continuous Emissions Monitoring System (CEMS). No independent third-party emissions stack-testing was performed at OGS during the LTB; however, compliance testing for particulates was performed at the biomass processing facility to satisfy requirements of the air construction permit for that facility. This section summarizes the activities and results of each test as they relate to air emissions, and provides overall conclusions on air emissions from the collective testing activities.

5.6.1 First Test Burn

The first cofire test, conducted over the period from November 30, 2000 through January 25, 2001, resulted in the burning of 1,269 tons of switchgrass at feed rates as high as 16.5 tons per hour, or about 3% of total heat input at OGS.[25] This test involved the use of temporary or test switchgrass feed equipment, some of which was rented—the test was a proof-of-concept exercise which had to be successfully completed prior to making further investments in biomass processing equipment. Unfortunately, the switchgrass feed process did not behave in a steady, consistent manner. The switchgrass feed rate varied between a few tons per hour up to 16.5 tons per hour. As

[25] W. Amos. 2002. *Summary of Chariton Valley Switchgrass Co-fire Testing at the Ottumwa Generating Station in Chillicothe, Iowa: Milestone Completion Report*. NREL/TP-50-32424. National Renewable Energy Laboratory, 67 Cole Boulevard, Golden, CO 8040-3393.

a result, the boiler was rarely able to achieve steady-state operation, and the boiler was not optimized for cofiring conditions. These conditions led to the collection of emissions data that were not deemed to be representative of continuous cofiring operations. In addition, because of the high-level of effort required to simply sustain switchgrass feed to the boiler, it was not possible to follow the data collection protocol as closely as planned. In particular, it was not possible to look back at the data set and correlate the continuous emissions monitoring system (CEMS) data with the cofiring rate (biomass input rate). This test was a learning experience from which emissions conclusions could not be confidently drawn, but from which the operational and procedural lessons were incorporated into the planning and execution of the subsequent cofire tests. Numerous improvements were made to the feed-handling equipment during testing. Fuel and ash samples were collected and boiler and emissions performance were analyzed to the extent possible.

The preliminary emissions-related findings of the First Test Burn were as follows:

- Opacity did not seem to change significantly during co-firing.

- PM and PM_{10} emissions appeared to decrease (by about 50% each) during co-firing. The large observed decrease in PM_{10} emissions, although desirable, was unexpected. This result warranted further testing which was performed during the Interim Test Burn.

- A one-day stack test indicated that CO emissions appeared to increase. Results obtained using a portable gas analyzer throughout the entire testing period indicated that on the day of the stack test, the boiler was operating irregularly. The portable gas analyzer results suggested that CO emissions did not increase during co-firing on other test days (i.e., when stack tests were not conducted). The CO emissions implications of switchgrass cofiring at OGS were not well understood following the first test burn. Further testing was required, and was performed during the Interim Test Burn.

- Daily-average NO_x emissions appeared to increase by about 6% (as measured by the CEM) during co-firing. This was unexpected due to the fact that the nitrogen content of switchgrass was about 50% of that for the Powder River Basin coal burned at OGS, and reductions or at least no increases in NO_x emissions had been measured during similar co-firing tests at other power plants. Further emissions testing was required to understand the effect of co-firing on OGS NO_x emissions during steady-state operations.

- Small decreases in SO_2 emissions were observed during co-firing. This is consistent with the lower S content of switchgrass relative to coal.

5.6.2 Interim Test Burn

One of the primary objectives for the Interim Test Burn was to acquire switchgrass cofiring emissions data suitable for making informed project decisions, while simultaneously supporting scientifically-sound air pollution regulation and energy policy. The emissions dataset obtained during the first cofire test was not sufficient for these purposes. With a great deal of cooperation from management and operations staff at OGS, IPL and the CVBP team were able to accomplish all of the testing objectives for the Interim Test Burn. A detailed description of the test planning, activities, and results is provided in the test report that was submitted to the Iowa Department of Natural Resources (IDNR).[26]

5.6.2.1 Summary of Test Conditions & Switchgrass Input

The Interim Test Burn was conducted during the first two weeks of December 2003. Pre-testing of biomass processing equipment and sampling techniques occurred between November 21 and 26, 2003. A maximum total of 2,000 tons of switchgrass was approved by the IDNR to be combusted during the Interim Test Burn time window; however, the project team's expectation was to burn a total of 1,300 tons or less. To meet the objectives of the Interim Test Burn, it was only necessary to burn an estimated total of 781 tons (1,673 bales) of switchgrass during the pre-test and testing periods combined. The average switchgrass feed rate during the December cofire testing was about 8.9 tons per hour, representing about 1.9 percent of the boiler's heat input. The maximum feed rate of switchgrass during the testing was estimated as 11.6 tons per hour. Average plant load during the tests was 95% of full load operation, or about 691 MW (gross). The average gross load during cofiring periods was 686 MW, and the average coal-only load was 696 MW--a difference of only 1.0%. The minimum average load on a test day was 646 MW (89% of full-load), and the maximum was 719 MW (99% of full-load). Soda ash addition rates were maintained constant throughout all required emissions testing. To minimize the variability of coal quality during testing, plant management arranged for all coal supplies during the testing to be from the same mine. All test plans were developed in cooperation with IDNR staff to ensure the test procedures met future needs for air permitting.

5.6.2.2 Interim Test Burn Equipment Upgrades & Data Collection

During planning efforts for the Interim Test Burn, the CVBP engineering team worked hard to identify and mitigate potential operational issues that could have a negative impact on the testing. Some of the rented equipment used in the First Test Burn was replaced by purchased equipment that, although still considered temporary, was representative of the processing system that would be incorporated into a potential permanent facility in the future if the project enters commercial operation. The newly purchased equipment included the following: a bale infeed conveyor, twine remover, debaler, debaler outfeed conveyor, larger airlocks, and meter bin modifications. This new equipment, and the experience gained during the First Test Burn, allowed more

[26] Antares Group Inc. "Chariton Valley Biomass Project Interim Test Burn Emissions Test Report." Submitted to Iowa Deparment of Natural Resources (IDNR). August 25, 2004.

problem-free operation of the switchgrass processing system during the Interim Test Burn. Illustrated photos of the biomass facilities and equipment for the Interim Test Burn are provided in Appendix B.

Data sampling procedures were also refined and more manpower was made available for collecting test performance data during the Interim Test Burn. Improved process control and automated data collection capabilities were installed in the biomass processing facility, including installation of biomass feed rate and on/off sensors that were tied into the main data acquisition system at OGS. This upgrade allowed automatic collection of biomass feed rates, on a minute-by-minute basis, corresponding to the emissions measurements collected by the Continuous Emissions Monitoring System (CEMS) at OGS. Emissions data from the 30-day period preceding any switchgrass firing was also collected from the OGS CEMS as a pre-test reference.

The project team collected coal, switchgrass, fly ash, bottom ash, and economizer ash samples for each test day, with switchgrass samples taken hourly during cofire testing. The following analyses were performed by Consol Energy (Pittsburg, PA) for daily coal and switchgrass fuel samples: ultimate and proximate analysis with heating value; sulfur, chlorine, alkali, and RCRA trace metal content; major ash elements; and ash fusion temperatures. Summary data for this laboratory testing is provided in Appendix K, including the test specifications and bid documents that were sent to several labs for competitive bidding. Emissions during the test period were estimated using CO2-based F-factors that were based on the coal and switchgrass sample analyses from each day and the heat-input rate for switchgrass. In addition to emissions measurements using the CEMS, GE Mostardi Platt[27] measured CO, O_2, CO_2, PM, PM_{10}, Hg, and Cl_2 emissions at various periods during the testing. A portable combustion analyzer was also used to continuously monitor CO emissions throughout the testing period. Illustrated photos of data acquisition equipment, sample collection activities, and test samples for the Interim Test Burn are provided at the beginning of Appendix K.

5.6.2.3 Summary of Emissions Results from CEMS

During the twelve days from December 1 to 12, switchgrass was fired on eight days. Four days were baseline (coal-only) test days. Since the data acquisition system was set up to indicate (on a minute-by-minute basis) periods when switchgrass was being fired and the feed rate, the project team was also able to analyze the coal-only periods *during the cofire test days*. To minimize the impact of changes in load and weather conditions, the hours from 8 am to 6 pm were chosen as the period for comparison of baseline and cofire data from the CEMS. In total, 3,933 minutes (65.6 hours) of baseline data and 3,173 minutes (52.9 hours) of cofire data was collected between the

[27] Results from the GE Mostardi Platt report will only be summarized in this report. Complete details of the GE Mostardi Platt test results are available in the following report, which has been provided under separate cover to IDNR: GE Mostardi Platt Report M22E0343A, *Particulate and Gaseous Emissions Study*, Elmhurst, IL, January 20, 2004

hours of 8 am to 6 pm.[28] The average CO2-based f-factor that is normally used to calculate emissions of SO_2 and NO_x at OGS in lbs/MMBtu, as approved by EPA and the IDNR, is 1,800 SCF CO_2 per MMBTU. Per request of IDNR, more detailed f-factor estimates were made to calculate the emissions for the Interim Test Burn. On average, the f-factor for the coal samples during testing was 1,866 SCF[29] CO_2 per MMBTU. The average f-factor for switchgrass was 1,936 SCF CO_2 per MMBTU. The average combined/blended f-factor for the test period was 1,867 SCF CO_2 per MMBTU. The blended f-factor was nearly identical to the coal-only f-factor (the difference is only 0.04%). A detailed example calculation is provided in Appendix C of the Interim Test Burn Emissions Report.[30] Overall results from analyzing the CEMS data during the 30-day baseline period (before any switchgrass firing began) and the test period are summarized below:

- SO_2 emissions decreased by an average of 4.7% when cofiring (0.649 lb/MMBtu) as compared to the coal-only periods (0.681 lb/MMBtu). These values are based on results obtained between 8 am and 6 pm from December 1 to 12 using CEMS measurements at one-minute intervals. This result was shown to be statistically significant and was expected. The decrease in SO_2 emissions is greater than the fuel-bound sulfur reductions resulting from the use of switchgrass. This is suspected to be due to the formation of greater amounts of potassium sulfate due to the additional potassium in the switchgrass (based on measured results from a very similar project in Denmark).

- SO_2 emissions were higher on average during the 30-day baseline period (10/16 to 11/20) that preceded any cofiring activity than during either the coal-only or cofire SO_2 emissions during the December test period. Based on hourly-averaged values for 24 hours per day, the average SO_2 emissions were as follows: 0.716 lb/MMBtu (30-day baseline average, coal-only), 0.655 lb/MMBtu (coal-only average during test period), and 0.624 lb/MMBtu (cofire average during test period). The higher SO_2 emissions average during the 30-day baseline period was most likely due to the use of different coal during that period as compared to the test period.

- NO_x emissions *were not changed by a statistically significant amount when cofiring*. Slight reductions in NO_x, or no significant increases, were the expected result prior to testing. NO_x emissions averages based on results obtained between 8 am and 6 pm from December 1 to 12, at one-minute intervals, were: 0.362 lb/MMBtu (coal-only average during test period), and 0.364 lb/MMBtu (cofire average during test period).

[28] Of the total 120 hours available between 8 am and 6 pm on the twelve test days, 118.4 hours are included in the CEMS emissions analysis. The 1.6 hours that is excluded from the comparison was due to: CEMS calibration or null data periods in the CEMS, and start-up and shut-down periods for the biomass system when the switchgrass feed rate to the boiler could not be accurately estimated.

[29] SCF stands for Standard Cubic Foot

[30] Antares Group Inc. "Chariton Valley Biomass Project Interim Test Burn Emissions Test Report." Submitted to Iowa Deparment of Natural Resources (IDNR). August 25, 2004.

- NO_x emissions were higher on average during the 30-day baseline period than during either the coal-only or cofire NO_x emissions during the December test period. Based on hourly-averaged values for 24 hours per day, the average NO_x emissions were as follows: 0.374 lb/MMBtu (30-day baseline average, coal-only), 0.360 lb/MMBtu (coal-only average during test period), and 0.362 lb/MMBtu (cofire average during test period). The higher 30-day baseline average was most likely due to two factors: 1) the use of different coal during that period as compared to the test period, and 2) periods of lower load that were experienced during the 30-day baseline period (even though the overall average load for the 30-day period was similar to the average loads experienced during the test period).

- Opacity increased by an average of 0.4% when cofiring, from a baseline average of 17.1% to a cofiring average of 17.5% (these averages are based on measurements obtained between 8 am and 6 pm from December 1 to 12). This result was shown to be a statistically significant result. Based on observations during the first cofire test burn, this increase was not an expected result. One possible explanation could be that cofiring caused a decrease in mean particulate diameter, caused by the formation of increased amounts of small-diameter potassium sulfate or other compounds. This higher number of small-diameter particles may scatter enough light during the opacity measurements to create increased opacity readings even though total measured particulate emissions (from contracted emissions testing) decreased during the same test period. This behavior has been observed in other biomass combustion projects.

- Average opacity was slightly lower during the 30-day baseline period than during either the coal-only or cofire opacity readings during the December test period. Based on hourly averaged values *for 24 hours per day*, the average opacity readings were: 16.4% (30-day baseline average, coal-only), and 16.7% (coal-only average during test period). This coal-only test period opacity average is different than the coal-only test period average reported in the previous bullet because one is based on 24 hours per day, and the other is based only on the hours between 8 am and 6 pm. Since opacity tends to increase over the course of a run period between outages at OGS, the lower opacity during the baseline period preceding the cofire testing was not unexpected.

- The average gross load was very close during the 30-day baseline period to that during the cofire test period. The average gross loads, based on 24 hour averages, were: 685.0 MW (30-day baseline average, coal-only), 688.7 MW (coal-only average during test period), and 681.3 MW (cofire average during test period).

5.6.2.4 Summary of Results from Contracted Emissions Testing

The following bullets summarize the results from the emissions monitoring activities performed by GE Mostardi Platt (CO, PM, PM_{10}, Hg, Cl_2) and Antares Group (CO):

- No increases in CO were observed during cofire testing, as measured by GE Mostardi Platt in the stack and by Antares Group at the air heater outlet. This was an expected and important result. Anomalies unrelated to the cofiring project created unusually high CO emissions results on the day of certified stack testing during the first cofire test burn (Winter of 2000/2001). Similar circumstances occurred on several occasions during this test period, but the combination of a greater number of hours of CO monitoring during this test burn and the coincidence that the limited-duration CO emissions spikes occurred during coal-only testing demonstrates that *CO increases were not created by firing switchgrass*.

- Six test runs were performed by GE-Mostardi Platt to measure total particulates (PM) and PM_{10} emissions. Three runs were performed during coal-only firing and three were performed during cofire operation. The coal-only tests were performed on Dec. 9, and cofire tests were performed on Dec. 10. On average, total particulates emissions were 4.4% lower during the cofire testing (0.0324 lb/MMBtu) as compared to the coal-only test runs (0.0339 lb/MMBtu). The average PM_{10} emissions during the cofire periods were 13.7% lower than during coal-only testing, at values of 0.0221 lb/MMBtu and 0.0256 lb/MMBtu, respectively. The average load and stack gas flow during the cofire particulates test runs were about 5% lower than during the coal-only testing. Average opacity readings were 0.5% higher during the cofire particulates test runs (18.4%) than during the coal-only (17.9%) particulates test runs.

- Two particulates test runs (1 each, cofire and coal-only) were performed at nearly identical gross loads of about 653 MW. Total particulates emissions were 6.0% lower during the cofire test run (0.0311 lb/MMBtu) as compared to the coal-only test run (0.0331 lb/MMBtu). The PM_{10} emissions during the cofire period were 9.7% higher than during the coal-only test, at values of 0.0249 lb/MMBtu and 0.0227 lb/MMBtu, respectively. Average opacity readings were 1.2% higher during the cofire particulates test run period (19.2%) than during the coal-only (18.0%) particulates test run. Although comparison of these two test runs shows an increase in PM_{10} when cofiring with switchgrass, the overall average PM_{10} readings for all of the test runs was lower when cofiring (as described in the previous bullet).

- To help interpret particulates emissions results, fly ash samples collected using an automatic fly ash sampler on coal-only and cofire test days were sent to a laboratory for resistivity testing. Comparison of the results for samples from Dec. 9 (coal-only test day) and Dec. 10 (cofire test day) indicates that the fly ash resistivities were nearly identical in the temperature range relevant to the OGS precipitator. The same resistivity curves can be used to demonstrate that the fly ash resistivity was likely to be higher during the cofire particulates emissions test runs as compared to the coal-only particulates test runs. The cause of the increased resistivity on the cofire test day would have been due to a 30^{o}F lower ambient temperature on the cofire test day compared to the coal-only test day.

- After review of all of the results mentioned above that are related to particulates emissions, it seems reasonable to conclude that small reductions (4 to 6%) in total particulates could be expected when cofiring under comparable loads and ambient temperature conditions. Results based on PM_{10} measurements are not as conclusive. It should be noted that the ash content of switchgrass, on an as-received lb/MMBtu basis, was about 12% (for 13% moisture content in switchgrass) less than that of the average coal sample during the testing.

- The final two test days, Dec. 11 and 12, were used to conduct optional mercury and chlorine emissions testing. Six test runs were conducted: 3 each under coal-only and cofire conditions. On average, a 7.3% reduction in total speciated mercury emissions was measured when cofiring switchgrass compared to coal-only firing. The average coal-only total speciated mercury emission rate was 0.0000109 lb/MMBtu while the cofire rate was 0.0000101 lb/MMBtu. The average chlorine emissions rate increased 10.5% when cofiring with switchgrass, from a coal-only average of 0.0019 lb/MMBtu to 0.0021 lb/MMBtu. Although switchgrass has less than half of the mercury content than the average coal fired during the test, most of the difference in mercury emissions between the two test days is thought to be attributable to differences in the mercury contents of the coals (based on the coal analyses for each day—Hg content in the coal sample on the coal-only day was 0.120 ppm, and 0.065 ppm on the cofire test day). Due to the very low chlorine content of the coals used at OGS, chlorine increases are expected when cofiring due to the increased chlorine content in the switchgrass. It should be noted that the chlorine content in the coal sample taken on the coal-only day was significantly higher than the chlorine content in the coal sample taken on the cofire test day (29 ppm vs 13 ppm, respectively). Testing and studies have shown that increased levels of chlorine, whether injected or inherent in the fuels, tend to increase mercury oxidation in flue gas.[31,32,6] Oxidized mercury is more easily removable from flue gas than elemental mercury.[33] "Higher levels of coal chlorine content have been significantly correlated with an increase in mercury capture and a decrease in percent of elemental mercury for

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[31] US EPA, Control of Mercury Emissions from Coal-fired Electric Utility Boilers: Interim Report, Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-600/R-01-109, April, 2002.

[32] Gale, T.K., Merritt, R.L., and Cushing, K.M. (Southern Research Institute), and Offen, G.R. (Electric Power Research Institute), *Mercury Speciation as a Function of Flue Gas Chlorine Content and Composition in a 1 MW Semi-Industrial Scale Coal-Fired Facility*, Proceedings of the Combined Power Plant Air Pollutant Control Mega Symposium, Washington, DC, May 19-22, 2003.

[33] Benson, S.A. (Energy & Environmental Research Center, Grand Forks, ND), *How Does Western Coal Affect Mercury Emissions?*, EM (Air & Waste Management Association's magazine for Environmental Managers), Pittsburg, PA, October, 2003.

all classes of particulate control,"[34] including in hot-side ESPs (ESP = electrostatic precipitator) such as that at OGS.

5.6.3 Air Permitting Issues and Summary

Antares Group prepared draft and final versions of the emissions results report from the Interim Test Burn and submitted it to Alliant Energy for review, comment, and approval. Alliant's engineering and environmental staff reviewed and approved the report and it was submitted to the IDNR. A meeting was held in early September 2004 with IDNR staff to discuss the emissions results from the Interim Test Burn and plans for future testing. Six staff members from IDNR's Air Quality Bureau, including the bureau chief, attended the 2.5 hour meeting and discussion. The IDNR was pleased with the report and presentation and indicated that they would like to proceed on a path to permit the project as a permanent addition at OGS since it did not appear as if the project would exceed any PSD limits for the OGS permits. Consultation with EPA for final determination was the next step.

Project team members from CVRC&D, Alliant Energy, and Antares met with IDNR and EPA air permitting staff to develop a specific strategy for submitting air quality permits for the new biomass processing facility that was planned to be built for the Long Term Test Burn and commercial project operations. Based on the reported results from the Interim Test Burn and the emissions projections for the Long Term Test Burn and the 25 ton per hour commercial operation, IDNR and EPA staff advised the project to submit a permit application for the 25 ton per hour commercial operation. This set the stage to permit the commercial operation in advance of the Long Term Test Burn.

With assistance from Chariton Valley RC&D, Inc. (CVRC&D), Alliant Energy, TR Miles, and BCCE, Antares assembled the permitting package for the project. CVRC&D and Alliant Energy submitted the applications during January 2006. The application package included all of the required forms for the new biomass processing facility and changes that will be required for OGS's operating permits, a copy of a project briefing paper describing all emissions-related issues, a set of drawings for the new facility, the final emissions report from the Interim Test Burn, and an air dispersion modeling report that Alliant Energy contracted with Stanley Consulting in Iowa to perform at the request of IDNR and EPA. The CVRC&D and Alliant Energy/IPL received all air permits, permit modifications, and approvals required to operate the switchgrass processing facility at OGS at a rate of 25 tons per hour on a commercial basis to provide switchgrass as a supplemental fuel for OGS. Approvals were obtained from both IDNR and EPA. The permit application documents are provided in Appendix L, and the resulting permits and approvals are included in Appendix M.

Alliant Energy/IPL added switchgrass as an approved fuel to its Title V air permit, with the switchgrass processing facility and its associated emissions being considered as a

[34] Benson, S.A., *Air Quality II Conference (Summary)*, Air Quality II Proceedings, Energy & Environmental Research Center, Grand Forks, ND, Sept. 19-21, 2000.

supporting operation to the OGS facilities. For the Title V operating permit program, the OGS Switchgrass Processing Facility is considered part of a major stationary source (OGS). In addition, CVRC&D obtained two Air Quality Construction Permits from the IDNR (IDNR Permits Number 05-A-233 and 05-A-234), one each for both 12.5 ton per hour processing lines in the proposed facility. A new air construction permit application will have to be submitted if the second process line is installed in the future because the approved construction deadline for the existing permit has expired. Finally, CVRC&D obtained a separate Title V permit for the OGS Switchgrass Processing Facility. Even though OGS and the Switchgrass Processing Facility each have separate Title V operating permits, they are still considered one major stationary source for Title V applicability purposes.

5.6.4 Long Term Test Burn

Prior to the completion of the new biomass processing facility, considerable time was spent preparing for the Long Term Test Burn. Coordination was planned between the operations staff at OGS, Alliant's IT staff, and other contractors who had operations and reporting responsibility for the test burn task. The central purpose of the test was the evaluation of potential long term impacts to the boiler and the ability of the system to operate smoothly over an extended period of time. The air emissions during cofiring and coal-only periods were also measured with the intent of evaluating their potential monetized value during a commercial operation, and to document emissions differences (if any) during a much longer period test than had been performed previously. No contracted stack emissions tests were performed at OGS during the Long Term Test Burn. All emissions monitoring and evaluation was done using data from the OGS CEMS.

In addition, to satisfy requirements of the air construction permit (IDNR Permit #05-A-233) for the biomass processing facility, the project team was required to conduct PM and PM_{10} emissions testing at the baghouse exhaust of the processing system. The allowable permit limits for PM and PM_{10} are 1.29 lbs/hr, and the allowable permit limit for opacity is 40%. The test results fulfilled the requirements of testing for the IDNR. PM emissions were measured as 0.22 lbs/hr, and the opacity was measured at 0.0% under full-load processing conditions.[35]

During the Interim Test Burn, emissions for carefully planned periods of switchgrass cofiring and coal-only operations were measured and compared. This offered the advantage of having fairly controlled, comparable conditions for comparison of cofiring versus coal-only operations. The drawback of the emissions results from the Interim Test Burn was that they were obtained over a fairly limited period of time (a two week period). During the Long Term Test Burn, the opposite situation existed. Emissions were measured over a longer period of time (about 3 months); however, the objective of

[35] Summary information for the particulates testing for the switchgrass processing facility is included in Appendix I of this report: Comprehensive Emissions Services Inc., "*Emissions Test Report for Chariton Valley RC&D on Switchgrass 1 (EP SWG1)*," March 22 & 23, 2006.

the Long Term Test Burn was to have continuous biomass system operations. No coal-only periods were preplanned during the cofiring test period. In an effort to obtain the best possible emissions data for meaningful comparisons during the Long Term Test Burn, the project team used the unplanned outage periods for the biomass processing system to obtained the coal-only emissions data. When an outage of the biomass system occurred, emissions data for the period immediately before the outage was used as cofiring emissions data and the emissions during the outage, once all biomass flow to the boiler had ceased, was used as coal-only emissions data. If plant loads or other operational conditions changed significantly before or during the biomass processing system outage period, the emissions data for both cofiring and coal-only operations for that period were excluded from the emissions comparison analysis. This approach helped ensure, to the greatest extent possible, that the emissions comparisons of cofiring and coal-only operations during the Long Term Test Burn were obtained under comparable operational conditions (i.e., on average for the data compared, similar coals were used during cofiring and coal-only operations, similar weather conditions were experienced, soda ash feed rates were the same, etc.).

Exhibit 90 shows the emissions comparison results for the Long Term Test Burn. In addition to air emissions, coal and combustion air feed rates and plant loads were also tracked during the emissions analysis periods. All data used for Exhibit 90 was obtained from data points in the OGS *EtaPRO* data acquisition system. For the periods analyzed, the heat input from biomass was measured to be about 1.5% of the total heat input for the plant. The overall gross plant load during the coal-only periods was about 597 MW, or about 0.5% higher than the average gross plant load (594 MW) during the co-firing periods. During cofiring periods, average coal flows were measured to be about 2% less than during the coal-only periods—about 0.5% of that reduced coal flow was attributable to the 0.5% higher load during the coal-only periods, and the remaining 1.5% coal flow reduction is estimated to have been due to the heat input from biomass.

Exhibit 90 Comparison of Cofiring to Coal-Only Operation

		Flow & Load Parameters				*Air Emissions*		
	Date & Time	**% Coal Flow**	**% OGS Air Flow**	**Gross Plant Load, MW**	**Net Plant Load, MW**	**NOx, lb/MMBtu**	**SO2, lb/MMBtu**	**Opacity, %**
COFIRING OPERATION: Biomass Feed Rate = 10.7 ton/hr								
Period Start Time	2/24/06 10:51	73.9%	72.4%	594.4	553.3	0.340	0.621	14.4%
Period Stop Time	5/9/06 16:46							
COAL-ONLY OPERATION: Biomass Feed Rate = 0 ton/hr								
Period Start Time	2/24/06 7:26	75.9%	73.4%	597.4	556.1	0.363	0.631	13.2%
Period Stop Time	5/9/06 15:51							
Parameter Differences: Cofire vs Coal Only Operations								
Cofire minus Coal-only Operations		-2.0%	-1.0%	(3.0)	(2.8)	(0.023)	(0.009)	1.2%
		Percent Difference in Emissions ==>				-6.3%	-1.5%	9.4%

The estimated biomass heat input was inferred from the gross load and coal flow measurements mentioned above (Biomass Heat Input during Cofire Periods = Reduced Coal Flow During Cofire Periods – Increased Gross Load During Coal-only Periods = 2.0% - 0.5% = 1.5%). The switchgrass feed rate to the OGS furnace during the cofiring periods analyzed for emissions comparisons was 10.7 tons per hour.

Combustion air flow rates during the cofiring periods were 1% less than during the coal-only periods, even though the average gross loads during the coal-only periods were 0.5% higher. This may be related to the significantly higher fuel-bound oxygen content in the switchgrass as compared to coal.

Sulfur dioxide emissions were 1.5% lower during cofiring periods, indicating a one-to-one SO_2 reduction with the rate of heat input obtained from biomass (i.e., a 1.5% heat input rate from biomass reduced the overall average SO_2 emissions by 1.5%). This was the expected result, and was the basis for how sulfur emissions reductions were estimated throughout the Long Term Test Burn as part of the biomass processing agreement between IPL and CVRC&D. The average SO_2 emissions rate while cofiring was 0.621 lb/MMBtu, compared to an average rate of 0.631 lb/MMBtu during coal-only operations.

As observed during the Interim Test Burn, opacity measurements when cofiring switchgrass increased. On average, opacity increased by about 1.2 opacity percentage points when cofiring. The average measured opacity during cofiring operations was 14.4%, while the average opacity during coal-only periods was about 13.2%.

Finally, nitrogen dioxide (NO_x) emissions measured during the Long Term Test Burn cofiring periods were about 6.3 percent lower than during the coal-only periods. The average NO_x emissions rate while cofiring was 0.340 lb/MMBtu, compared to an average rate of 0.363 lb/MMBtu during coal-only operations. Slightly lower NO_x emissions would not have been surprising due to the slightly lower fuel-bound nitrogen content of switchgrass; however, differences in fuel-bound nitrogen content would not explain the level of reductions measured and presented in Exhibit 90. NO_x emissions are far more complicated to predict than SO_2 emissions, since NO_x emission can generally be impacted by a much wider range of factors (furnace temperature, fuel nitrogen content, combustion staging, mixing and flow conditions within the furnace, etc.). Detailed combustion modeling may indicate the root cause for measured NO_x reductions when cofiring switchgrass in the current firing configuration at OGS. In the absence of detailed combustion modeling that may further explain the reason for NO_x reductions when cofiring biomass at OGS, the conservative approach would be to assume that no reductions occur. If documenting NO_x reductions were of continued interest or importance for cofiring operations at OGS during potential future cofiring operations, a fairly automated calculation routine using the same procedures used in the preparation of the data in Exhibit 90 could be implemented and performed on an ongoing basis in the OGS data analysis system, or on a periodic basis using data exported from the OGS data system.

5.6.5 Conclusions & Projections for Future Operations

Based on results described in the sections above for measurements made during the project's test burns, the two tables shown in Exhibit 91 state expected changes in pollutant emissions at OGS for two separate periods: 1) the Long Term Test Burn, and 2) during planned future commercial operations for the biomass cofiring project at an annual switchgrass firing rate of 100,000 tons (based on 12.5 tons/hour average switchgrass feed rates). Emissions changes for a commercially operating project at the project's original long-range objective of firing 200,000 tons per year at OGS could be obtained by simply doubling the figures in the commercial operations column in Exhibit 91. Using the average measured results for each emission monitored during the project's test burns, only chlorine emissions would be expected to be increased during the planned commercial operation.

Exhibit 91 Estimated Emissions Changes for Test Burn & Commercial Operation

Pollutant	Ave Coal lb/MMBtu	Ave Cofire lb/MMBtu	% Change[1]	Source
SO2	0.631	0.621	-1.5%	Long Term Test Burn Measured Results
NOx	0.363	0.340	-6.3%	
PM	0.0339	0.0319 to 0.0324	-6.0% to -4.4%	General Electric/Mostardi Platt (GE-MP) measurements during Interim Test Burn
PM-10	0.0256	0.0221 to 0.0281	-13.7% to 9.7%	
Total Speciated Mercury	0.0000109	0.0000101 to 0.0000107	-7.3% to -1.4%	
Chlorine (Cl2)	0.0019	0.0021	10.5%	
CO	0.00026	0.00025 to 0.00026	-3.8% to 0.0%	
Opacity	13.2%	14.4%	n/a	Long Term Test Burn Measured Results

Pollutant	Estimated Net Change in Emissions due to Cofiring Switchgrass with Coal[1]		
	Commercial Operation,[2] tons/yr	Long-Term Test Burn	
		lbs.	tons
SO2	-351	-134,070	-67.0
NOx	0 to -681	0 to -259,939	0 to -130.0
PM	-61 to -45	-23,416 to -17,133	-11.7 to -8.6
PM-10	-105 to 74	-39,978 to 28,327	-20.0 to 14.2
Total Speciated Mercury	-0.024 to -0.005	-9.14 to -1.74	-0.0046 to -0.0009
Chlorine (Cl2)	6.0	2,284	1.1
CO	-0.30 to 0.00	-114.2 to 0.0	-0.1 to 0.0
Opacity	n/a	n/a	n/a

NOTES:

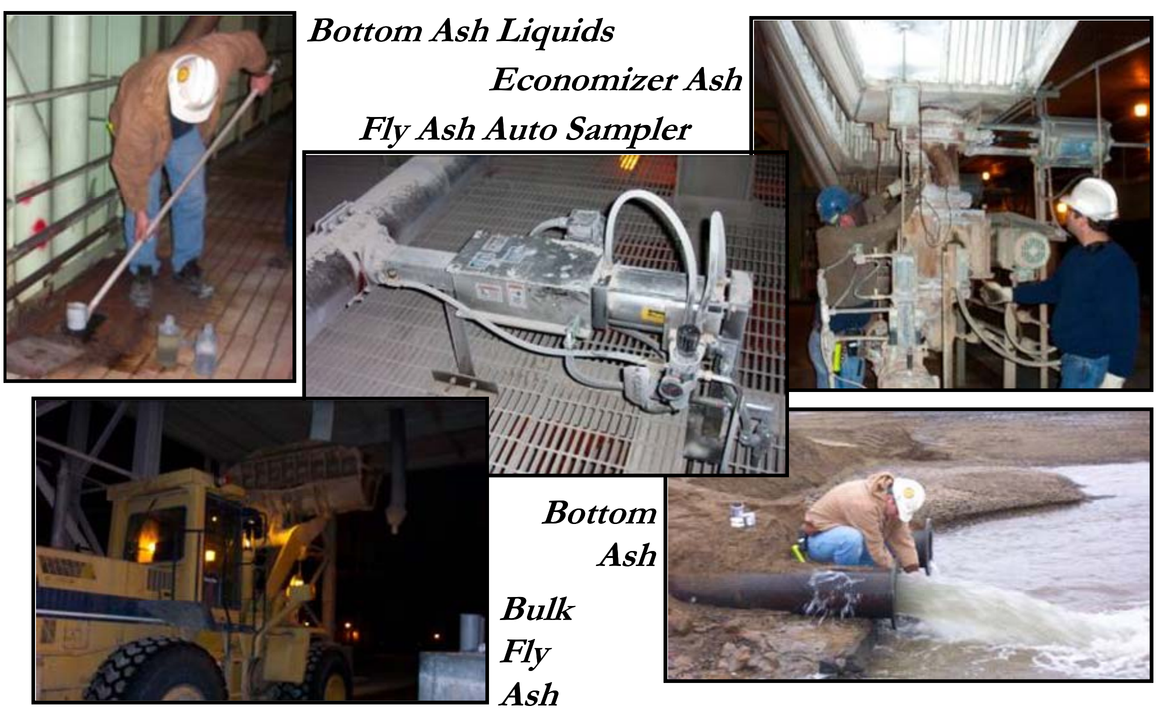
1) Negative numbers indicate decreases relative to coal-only operation, and positive numbers indicate increases.

2) Commercial operation estimates are based on firing 100,000 tons of switchgrass per year at 2.5% average heat input from switchgrass.

5.7 Ash-Related Impacts

During the project's three test burns, ash samples were collected during cofiring and coal-only operations at OGS. Samples of fly ash, bottom ash, and economizer ash were collected and analyzed (as illustrated in Exhibit 92). The purpose of this sampling was to characterize differences in the ash obtained from cofiring and coal-only operations, and to investigate specific issues such as: 1) the performance and properties of fly ash from cofiring operations when used as an ingredient for making concrete, 2) the extent of unburned carbon (also referred to in this section as Loss-On-Ignition, or LOI) in the plant's various ash streams during cofiring operations compared to coal-only operations, and 3) to obtain key laboratory analysis data on the ash samples, including fly ash resistivity testing for judging potential impacts on the electrostatic precipitators. The issue of primary importance with respect to ash from cofiring operations was whether Alliant Energy / IPL could gain approval from the IDOT to use fly ash from cofiring operations as an ingredient for concrete. Sales of fly ash for concrete end-uses is a very important source of revenue at OGS, and if cofiring biomass jeopardizes that revenue stream, the prospects for a commercially operating biomass cofiring application at OGS would be severely hampered (very likely eliminated under all reasonably foreseeable scenarios). This section summarizes and presents some of the key results obtained from ash sampling, testing, and analysis from the project's test burns.

Exhibit 92 Ash Sampling Techniques and Locations



5.7.1 Laboratory Testing of Fly Ash, Bottom Ash, and Economizer Ash

Complete laboratory test results, as well as the specifications for the laboratory testing, for fly ash, bottom ash, and economizer ash samples that were collected during the Interim and Long Term Test Burns are included in Appendix K. Careful efforts were made to empty ash hoppers where sampling occurred prior to the beginning of a test when ash would be sampled. Typically, ash was allowed to accumulate in the hoppers for a period of four to eight hours. Ash samples were then taken from the hopper or silo prior to or while emptying the hopper/silo. The one exception to this was sampling of fly ash via an in-line automatic sampler. The automatic sampler was placed on the main fly ash discharge line between the electrostatic precipitator hoppers on the side of the furnace where switchgrass was burned. The automatic sampler obtained samples every couple of minutes, and discharged the samples into a collection bucket. Additional details on fly ash collection procedures are provided in Appendix N.

5.7.1.1 Loss-On-Ignition Results

Exhibit 93 and Exhibit 94 present the results from the Loss-On-Ignition testing for each type of ash at OGS. Loss-On-Ignition measurements are important because they are an indicator of the amount of fuel that was not completely burned in the furnace. Since the number of samples and the total volume of each sample were small, the numerical results from these tests should not be considered to be absolutely conclusive. The primary objective was to determine if there were consistent and significant problems with increased LOI when cofiring biomass. As can be seen in the results tables, LOI results in cofired ash samples were comparable to those from coal-only test periods and on average they were typically slightly lower. Based on these test results, it seems likely that any variance in LOI at the plant when cofiring may have much more to do with conditions affecting the unburned carbon from the coal (such as a problem with a coal mill) than from biomass. Possible exceptions to this would be if an unusually high moisture content biomass was fired, or if there was an undetected problem with the biomass milling equipment that impacted the sizing of the biomass (allowing larger biomass particles to be injected into the boiler).

Exhibit 93 Interim Test Burn Loss-on-Ignition Test Results

Firing Mode	Minimum LOI, %	Average LOI, %	Maximum LOI, %	No. of Samples
Bottom Ash Samples				
Coal-only	0.31	7.44	22.97	4
Cofire	0.17	1.63	5.01	7
Economizer Ash Samples				
Coal-only	0.01	0.03	0.07	3
Cofire	0.02	0.26	0.76	7
Fly Ash Samples				
Coal-only	0.22	0.27	0.31	3
Cofire	0.18	0.31	0.35	7

Exhibit 94 Long Term Test Burn Loss-on-Ignition Test Results

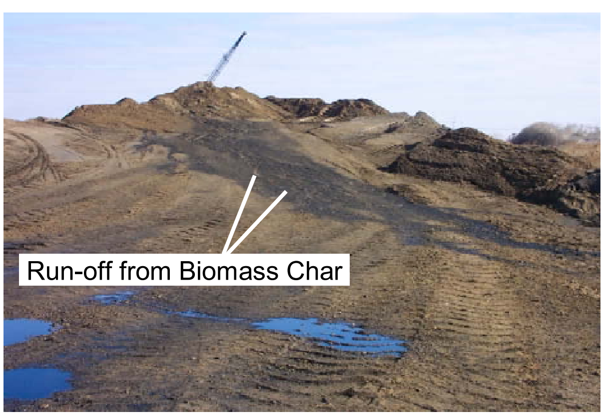
Firing Mode	% Loss-On-Ignition			No. of Samples
	Minimum	Average	Maximum	
Bottom Ash Samples				
Coal Only	0.51	1.04	2.03	3
Cofire	0.18	0.47	0.96	5
Fly Ash Samples				
Coal Only	0.51	0.92	2.03	4
Cofire	0.13	0.33	0.50	10

It should be noted that the unburned biomass is most visibly noticeable in the plant's bottom ash stream. It is present on a higher weight percentage basis in the bottom ash, and its visible and physical nature is significantly different than the balance of the bottom ash. Ash shown in Exhibit 95, the unburned biomass floats and collects around the edges of the ash pond. This did not appear to be a large problem for the customers using the plant's bottom ash; however, some complaints were received during the test.

Exhibit 95 Unburned Biomass Accumulation at Bottom Ash Discharge Pipe

Bottom Ash Discharge Pipes

Unburned Biomass Accumulation



Bottom Ash Pile, Biomass Char Run-off

Unburned Biomass (Close-up)

If the accumulation of unburned biomass around the bottom ash settling pond is a problem for the end users, it may be possible to remove a high fraction of the material by scooping around the edges of the pond periodically, particularly near the bottom ash discharge pipes. Once this condition was noticed during the Long Term Test Burn, operators at the biomass processing facility began making daily trips to the settling pond to remove most of the visible accumulated unburned biomass using a shovel and bucket.

Exhibit 96 and Exhibit 97 show a close-up of one of the bottom ash samples that was collected at the exit end of the bottom ash discharge pipe. Exhibit 97 and the lower photo in Exhibit 96 show the sample with the unburned biomass separated from the other bottom ash in the sample. Exhibit 97 also shows two distinct types of unburned biomass from the sample: 1) unburned switchgrass nodes, and 2) larger unburned pieces from non-switchgrass species. It should be noted that the sample shown in these two exhibits contained an unusually high amount of unburned biomass, and is shown here primarily as an example of the visible character of the unburned biomass that exits the furnace in the bottom ash stream.

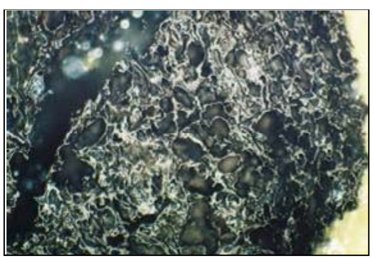
Exhibit 96 Bottom Ash Samples from Interim Test Burn

Exhibit 97 Unburned Switchgrass and Non-Switchgrass biomass

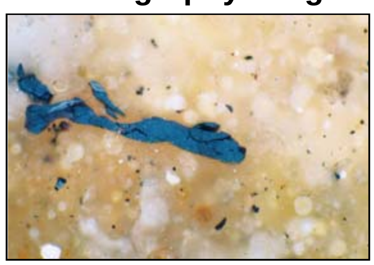
5.7.1.2 Petrography Results

In addition to testing to determine how much total unburned carbon was present in the ash streams, Alliant Energy staff wanted to determine what fraction of the unburned carbon was attributable to unburned biomass and what fraction was attributable to unburned coal. Tests were performed using ash samples collected during the Interim Test Burn. To accomplish this, Consol Energy developed a technique where the ash samples were ground up and cast into a 1-inch diameter epoxy plug. The plug was then sliced and polished. The content of each plug was then viewed under a high powered microscope by an expert geologist. The geologist divided each plug into 1000 grid squares, and classified the contents of each square as to whether it was a carbon form or not, and if so, whether the unburned carbon was from grass or coal. Exhibit 98 shows samples of unburned carbon from coal and grass, from each type of ash stream at the plant. The origin (grass or coal) of the unburned carbon is fairly easy to determine--the unburned carbon from grass is very cellular looking. Based on the results of these grid-by-grid classifications, the geologist was able to estimate the total percentage of the sample that was a carbon form, and what fraction of the total carbon forms were from grass and coal, respectively. Due to the expense of the tests, only a few samples of each type of ash were analyzed. Exhibit 99 shows the tabulated results from this testing. While the tests were too limited to be conclusive, they did indicate that all of the unburned carbon (in these samples) was from coal. Most (92%) of the unburned carbon in the one economizer ash sample tested was from coal. In two out of the three bottom ash samples analyzed, the majority of the unburned carbon was from grass (31% in one sample, and 92% in another bottom ash sample was unburned carbon from grass).

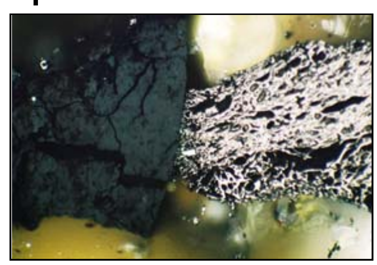
Exhibit 98 Petrography Image Samples



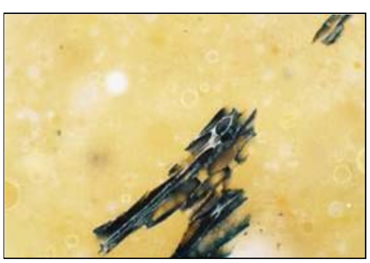
Coal Char, Fly Ash 12/11/03



Unburned Coal, Econ. Ash 12/11/03

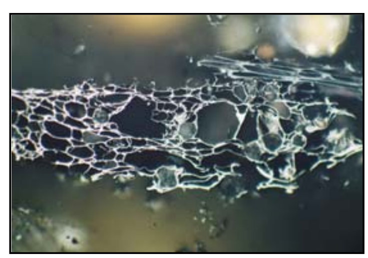


Unburned Coal & Char, Bottom Ash 12/7/03



Grass Char, Fly Ash 12/11/03

Grass Char, Econ. Ash 12/11/03



Grass Char, Bottom Ash 12/11/03

Exhibit 99 Petrography Results

Sample Date	Test Activity	Sample Description	Total Petrographic Carbon Forms, Vol %	% Carbon Forms from Grass	% Carbon Forms from Coal
12-05-03	Cofire, wet switchgrass from outdoor storage	BOTTOM ASH	1.6	31	69
12-07-03	Coal only	BOTTOM ASH	15.6	--	100
12-10-03	Cofire, "dry" switchgrass from indoor storage	BOTTOM ASH	0.6	--	100
12-11-03		BOTTOM ASH	9.2	93	7
12-10-03		ECONOMIZER ASH	2.6	8	92
12-11-03		ECONOMIZER ASH	0.2	--	100
12-11-03		FLY ASH	0.3	--	100
12-11-03		FLY ASH	0.1	--	100

5.7.2 Fly Ash Performance Testing and Approval

As mentioned previously, the ash-related issue of primary importance to the project was whether approval could be obtained for selling the plant's fly ash for use in concrete for construction projects. The cement admixture market, or the "ASTM C618[36] market," is the main revenue source from fly ash sales. At the beginning of the Chariton Valley Biomass Project, the fly ash generated at OGS and sold into the "ASTM C618 market" had to meet the requirements set by ASTM standard C618. ASTM standards, which are developed for materials, products, systems, and services, are "voluntary," since ASTM does not mandate their use. Government regulators, however, often endow "voluntary" standards with the force of law by citing them in laws, regulations, and codes. At that time, the Iowa Department of Transportation's (IDOT) paving activities consumed a significant amount of the OGS fly ash sold to the "ASTM C618 market," and IDOT required that the concrete used for its roads meet ASTM standard C618. Since the coal fly ash produced at OGS meets this standard, it is highly marketable to other consumers such as Ready Mix Concrete. Strictly interpreted, the ASTM standard C618 does not cover fly ash produced from coal cofired with other fuels such as biomass, even if the fly ash from the cofiring operation meets all of the performance requirements in the standards.

Rather than waiting on the ASTM standard to be changed or an alternative to be developed, the Chariton Valley project team sought to gain the Iowa Department of Transportation's approval for use of cofired fly ash from OGS by demonstrating that the fly ash from switchgrass cofiring operations meets the performance requirements of ASTM standard C618. The project team for this effort included ISG Resources and Dr. Scott Schlorholtz from Iowa State University (ISU). ISG Resources is the company contracted by IPL to market ash from OGS. Dr. Schlorholtz is a materials scientist from

[36] ASTM standard C618 is the specification for *Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete*.

Iowa State University and, at the time of the testing, he was the chair of the ASTM C618 committee. Dr. Schlorholtz is regarded as one of the country's top experts on C618 testing and issues.

Discussions with ISG Resources indicated that if cofired fly ash is not adopted by the ASTM C618 standard when commercial cofiring operations begin at OGS, ISG and Alliant could work with IDOT directly to develop the agency's own acceptance criteria for this material. If the results from ISU fly ash testing showed consistent quality and adequate results from concrete cylinder compression tests, IDOT may be willing to purchase the cofired fly ash even without strict ASTM C618 compliance. If it does, other customers in the "ASTM C618 market" such as Ready Mix could be willing to follow suit. This approach has been used successfully in other states such as Florida to gain DOT acceptance of cofired fly ash. That approval in turn proved to be the key to success in maintaining other customers in the ASTM C618 market. Such IDOT approval was required prior to initiating a Long Term Test Burn for the Chariton Valley Biomass Project, since that test burn would generate fly ash over a 3-month period. If IDOT approval had not been obtained prior to the Long Term Test Burn, the most valuable market for all of the fly ash from OGS would have been forfeited for the period throughout the test.

Appendix N contains a detailed description of the fly ash sampling and collection activities during the project's Interim Test Burn that provided the fly ash for use in the performance testing performed by Dr. Schlorholtz at ISU. Dr. Schlorholtz conducted a wide variety of tests on the fly ash samples collected during the Interim Test Burn. The purpose of this testing program was to evaluate both the uniformity and performance of the co-combustion fly ash. The scope of the testing program was limited to the determination of bulk fly ash properties, ASTM C 618 mandatory and supplementary optional tests, and a series of concrete tests. The results of the various performance tests were in good agreement with prior studies using OGS fly ash. Hence, it was concluded that the co-combustion of 2.5% switchgrass with coal had a minimal impact on the properties that are specified in ASTM C 618. In concrete performance testing, the study failed to find any significant differences between the baseline OGS fly ash and the samples of co-combustion fly ash. The complete details of Dr. Schlorholtz's fly ash performance testing are provided in a separate report.[37]

The test results discussed above, along with the sample collection methods during the test burn, were presented to key staff at the Iowa Department of Transportation (IDOT) during a meeting on June 29, 2005. The result of the meeting was a signed letter from IDOT granting permission for Alliant Energy and ISG Resources to sell fly ash from OGS for concrete uses with up to a 5% heat input rate from switchgrass. A copy of the letter is provided on the first page of Appendix N. This approval was a critical step that was required to allow the project to conduct the Long Term Test Burn and potentially

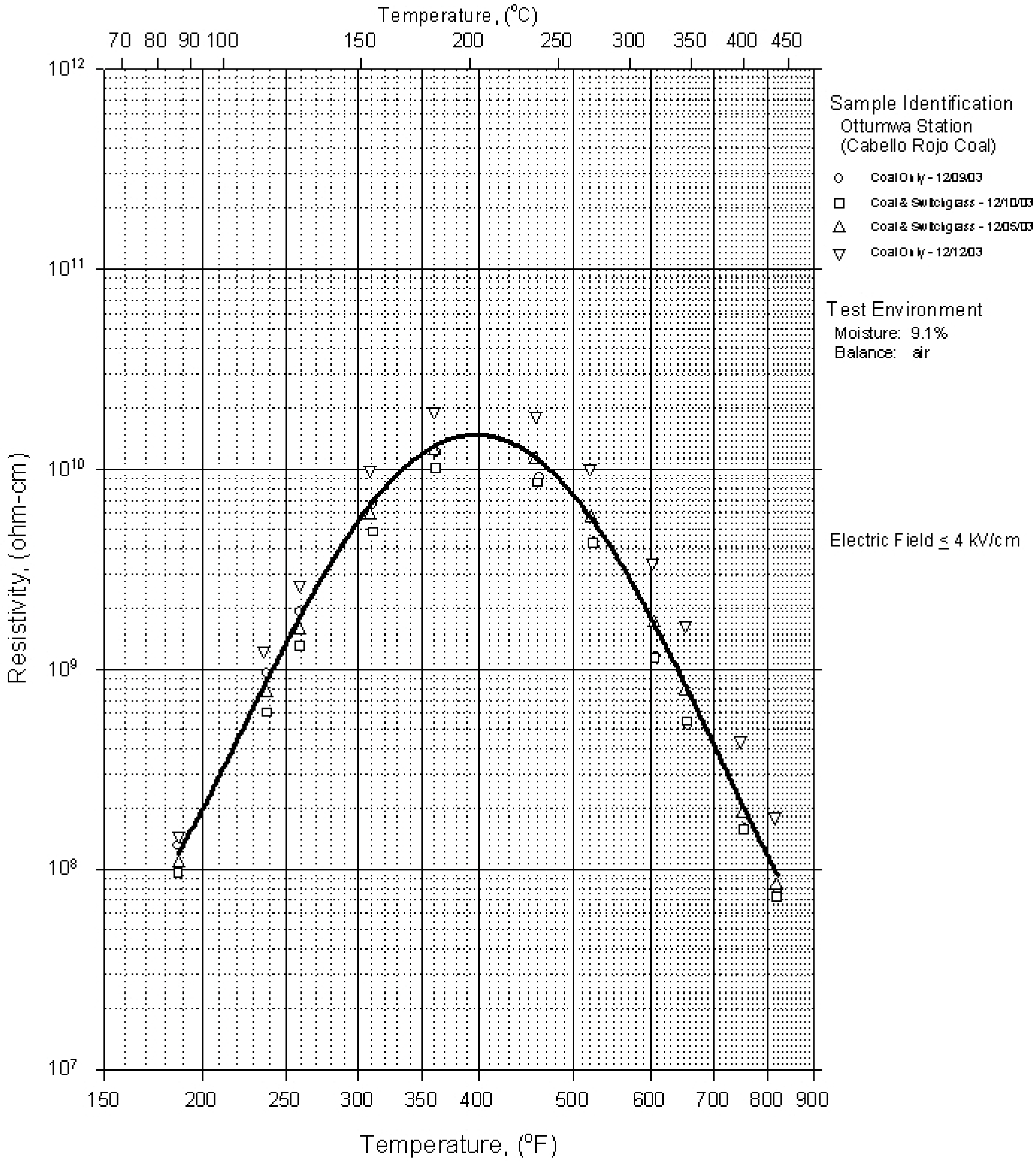
[37] Schlorholtz, Scott. "Testing Program for the Evaluation of Co-combustion Fly Ash Produced at Ottumwa Generating Station; Phase 2 (Second Trial Burn)." Chariton Valley Biomass Project. June 2005.

enter into a commercial operation afterwards. A construction project was chosen as a test for application and use of the fly ash from the LTTB, to allow long term field performance evaluations of the concrete produced from the fly ash from coal and switchgrass cofiring operations at OGS.

5.7.3 Fly Ash Resistivity Testing

To allow evaluation of the impacts of switchgrass cofiring on the performance of the plant's electrostatic precipitators for collecting fly ash, two coal-only and two cofired fly ash samples from the Interim Test Burn were sent to a laboratory for resistivity testing. Results are shown in Exhibit 100. At a given temperature, the resistivity of the coal-only fly ash samples were typically higher or equal to the samples from coal cofired with switchgrass.

Exhibit 100 Fly Ash Resistivity Test Results



5.8 Long-Term Power Plant Impacts of Cofiring

Stand-alone combustion of herbaceous biomass in heat and power-producing boilers has been known to cause severe problems with fouling, slagging, and chlorine-induced corrosion because of the relatively high contents of chlorine and potassium in these types of biomass (Baxter, 1998, Michelsen et al., 1998, Sander et al., 2000). On the contrary, co-combustion of coals and biomass fuels has been shown to decrease the adverse impacts of biomass, because the mineral constituents of coals may incorporate the potassium of the biomass into high-melting, less corrosive compounds. Among others, co-firing with up to 20%-wt. high-alkali straw has been successfully demonstrated at full scale (Sander and Wieck-Hansen, 2005, Hansen et al., 1999). The most important elements with respect to deposit formation and corrosion introduced by cofiring switchgrass are potassium (K) and chlorine (Cl). The content of these elements varies significantly in switchgrass, but especially in early harvest switchgrass which has a significantly higher content of K and Cl than the Powder River Basin coal used at the Ottumwa Generating Station.

Elsam Engineering A/S, a subsidiary of Danish Oil and Natural Gas (DONG), was contracted by the project to monitor and evaluate potential long-term boiler impacts. In order to quantify the effect of cofiring on corrosion, long-term exposure tests during normal operating conditions were required. The long-term tests were performed during two periods: from mid-January 2006 to mid-May 2006, and again from mid-May 2006 to mid-September 2006. The first period included 1675 hours of switchgrass cofiring (during the Long Term Test Burn), while the second period was during coal-only operations. The total exposure time during the first test period was 2880 hours. A similar testing procedure was followed during the second test period, to obtain a coal-only baseline for comparison to the samples and results obtained during the switchgrass cofiring test period. This section is intended to briefly summarize the results of this testing. Interested readers should refer to Appendix O for more details. A summary presentation, published paper, and detailed report on the test procedures and findings are included in Appendix O. Portions of this section are excerpted from those documents.

5.8.1 Investigation Methods

The deposition and corrosion testing was conducted through two means as illustrated in Exhibit 101. The first method used air cooled deposition probes (see Exhibit 102) inserted into the boiler during firing for short-term duration periods ranging from 3 to 24 hours for each deposition test. The second method used fixed (welded) coupons attached to boiler surfaces in strategic locations (see Exhibit 103)—these coupons (see Exhibit 104) remained in the boiler for the entire length of the test run (approximately 2,880 hours), and then were removed for laboratory analysis. The short-term tests were performed with stable and well-defined operational conditions. This ensured that complete and consistent data sets were established. In each measuring campaign, the deposit probes were exposed for three hours and samples of coal, switchgrass, and ash were collected and analyzed.

Exhibit 101 Corrosion and Deposition Test Locations and Method Summary

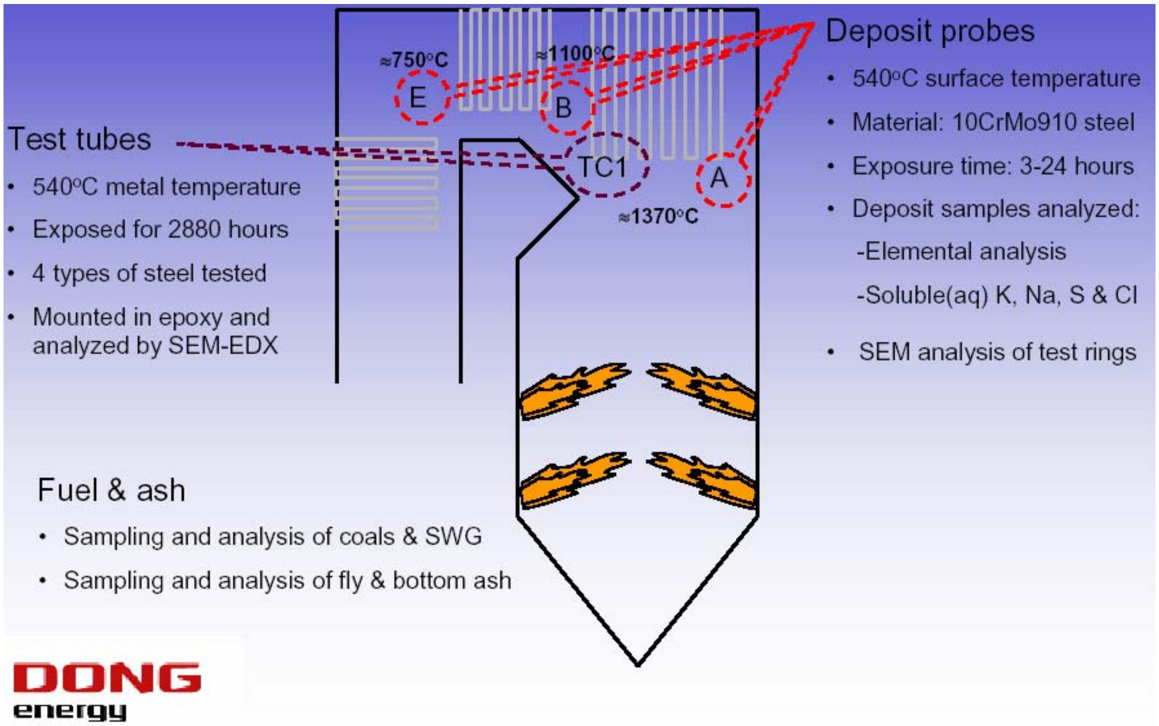


Exhibit 102 Hand Held Boiler Probe (right) and Deposition Collection Rings (left)

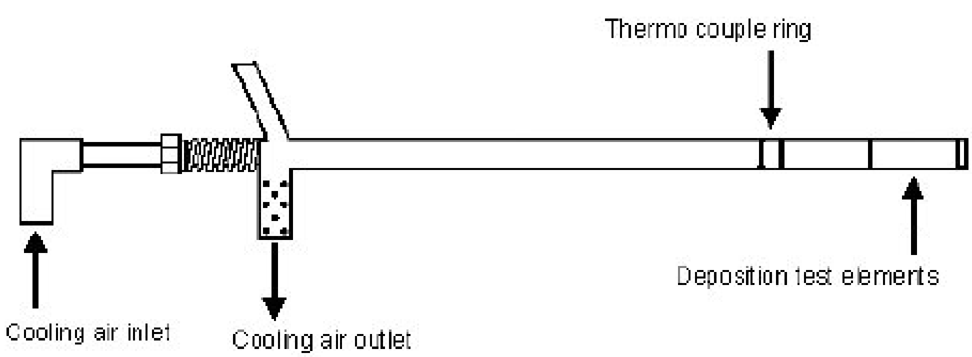


Exhibit 103 Boiler Convection Pass with Corrosion and Deposition Test Locations

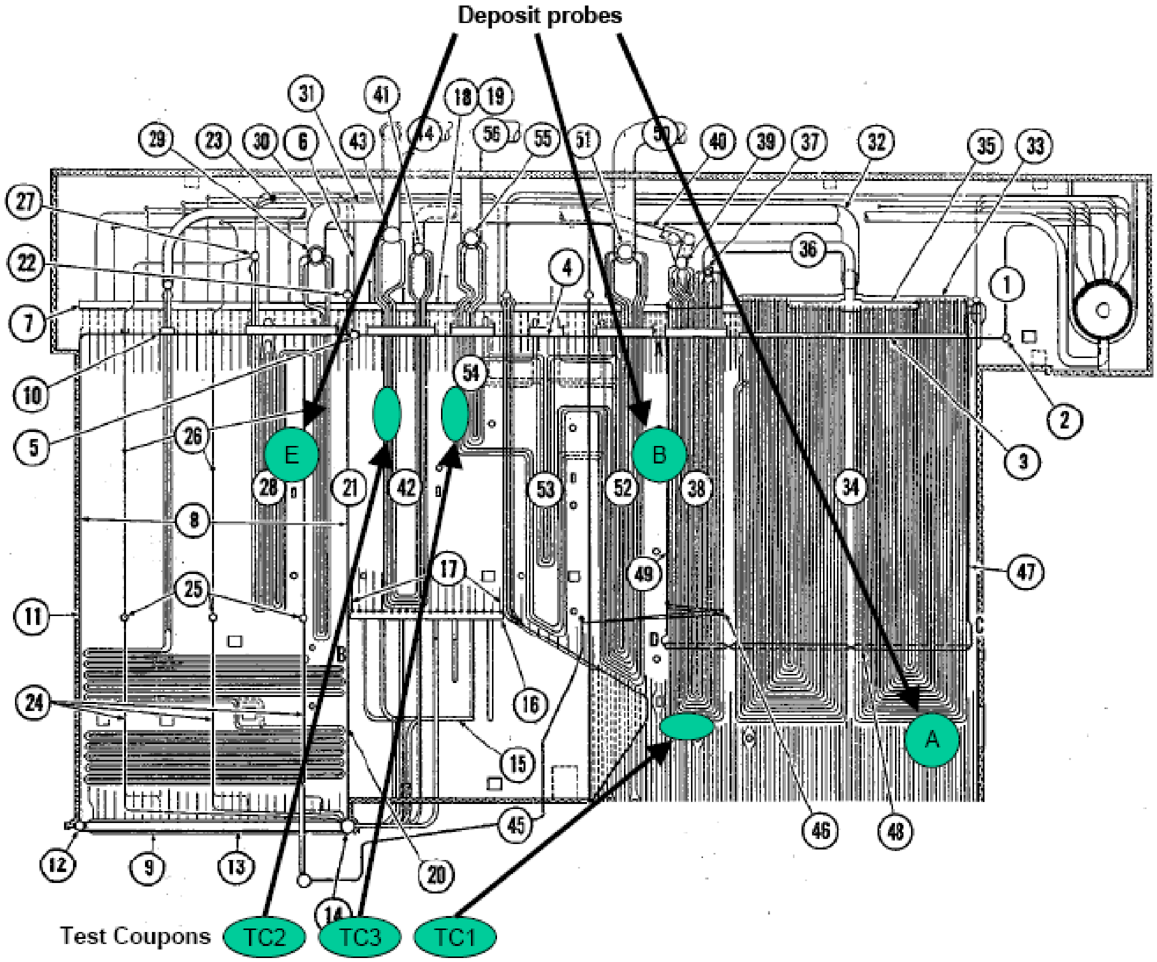


Exhibit 104 Test Coupons which were Welded into the Boiler

The general idea of the test plan was to perform short-term tests at 100% boiler load and at 50% boiler load with the switchgrass feed rate as close to 12.5 tons/hr during the entire period. Following this approach, the boiler load was used to change the switchgrass share. Both tests were repeated once. In addition, a 24-hour test was made under "normal load conditions." The maximum capacity of the switchgrass processing facility is 12.5 tons/hr, corresponding to a switchgrass share of approximately 3%-wt. (dry basis) at full boiler load, or 6%-wt. (dry basis) at half boiler load. The schedule for the deposition testing is shown in Exhibit 105. For the long-term exposure corrosion tests, the corrosion coupons were installed for a total of 4 months.

Exhibit 105 Test Schedule for Deposit Probe Measurements

Test #	*Date*	*Time*	*Boiler load*	*Exposure time (h)*
Co-firing				
1	22 March 2006	9.00-14.00	100%	3
2	22-23 March 2006	23.00-04.00	50%	3
3	23 March 2006	09.00-14.00	100%	3
4	23-24 March 2006	23.00-04.00	50%	3
5	24-25 March 2006	07.00-09.00	"normal load"	24
Coal reference				
1	3 July 2006	8.00-12.00	100%	3
2	3 July 2006	12.00-16.00	100%	3
3	5 July 2006	20.00-00.00	50%	3
4	6 July 2006	00.00-04.00	50%	3
5	6-7 July 2006	06.00-06.00	"normal load"	24

5.8.1.1 Deposit Probe Measurements

The effect of co-firing on the initial deposition rate and initial deposit chemistry was evaluated by the use of cooled deposit probes. A schematic illustration of the applied deposit probe is shown at the bottom of Exhibit 102. The probes were equipped with two exchangeable test rings for deposit collection and a thermocouple ring for metal temperature measurement in three circumferential positions. The surface temperature of the probe in all tests was maintained at a predefined value (540°C, or 1004°F) by automatic control of the flow of cooling air. Test rings made of 10CrMo910 steel (i.e., common superheater material) were utilized in all tests.

The positions of the deposit probe measurements were chosen to allow evaluation of the effect of co-firing on both high-temperature and low-temperature fouling. High-temperature fouling is important, as the increase in potassium from switchgrass may soften the silicates in this zone. Low-temperature fouling is also important, as the Powder River Basin coals have a high tendency towards this type of fouling, mainly due to the high content of Ca and the potassium from the switchgrass, which may affect this type of fouling. The probe measurements were made in three positions in the eastern part of the boiler as shown in Exhibit 101 and Exhibit 103: position A – before the

Division Panel section, position B after the Pendant Platen Section, and position E before the Low-Temperature Pendant Section.

As indicated in Exhibit 105, the deposit probes were exposed for three hours of the five-hour test. Two supplementary long-term tests were conducted for a period of 24 hours at normal load for the coal-only reference and for the co-firing period. Each test included simultaneous measurement in all positions (i.e. three probes).

After exposure, the test rings were dismantled with great care to ensure that no deposit was removed. In the laboratory, by use of a preformed shape, deposits were carefully removed on the upstream and downstream side respectively. The weights of upstream and downstream deposits were subsequently measured so that the deposition fluxes could be estimated. The composition of the upstream and downstream deposits was analyzed for the elements S, Cl, P, Si, Al, Fe, Ca, Mg, K, Na, Ti, and water-soluble Na and K. For selected tests, a part of the deposit was left on the test ring for epoxy impregnation and scanning electron microscope (SEM) analysis.

5.8.1.2 Corrosion Tests

The corrosion tests included both analysis of the deposit probes and the installed corrosion test tubes (or “coupons”). The deposit probes were exposed in positions A, B, and E indicated in Exhibit 101 and Exhibit 103. The probes are made of 10CrMo910 with 2.0-2.5 %Cr and 0.90-1.10 Mo. During operation, they had 540°C (1004°F) metal temperature and varying flue gas temperatures where A≈1370°C (2498°F), B≈1100°C (2012°F), and E≈750°C (1382°F). The exposure time was 3 hours.

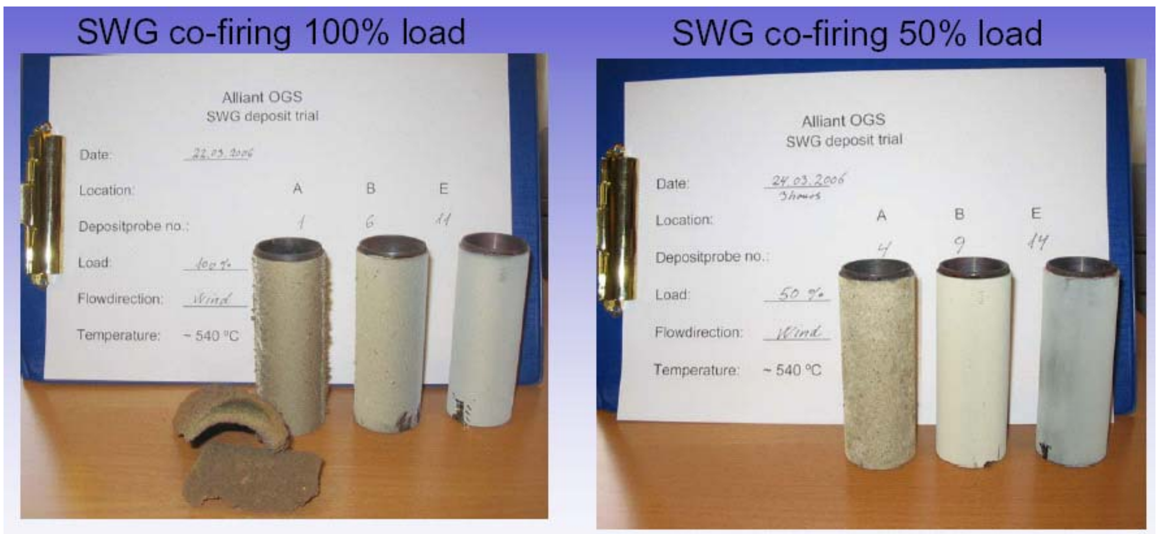
Test tubes (or “coupons”) for quantification of corrosion rates were installed in the most critical parts of the superheaters (position TC1, TC2, and TC3) as shown in Exhibit 103. The corrosion probes were installed for a total of four months (2880 hours); however, co-firing of switchgrass only occurred during 1675 hours towards the end of the installation period. After exposure, the test tubes were removed, mounted in epoxy resin and metallographically prepared for scanning electron microscope (SEM) investigation. The steam temperature was 540°C (1004°F), and the gas temperature was approximately 1350°C (2462°F) in position TC1.

All of the specimens analyzed in this work were positioned in the TC1 location. The steel alloys investigated were 10CrMo910, 13CrMo44, 347H, and 304H—each specimen contained five sections welded together, each about 8 inches long. Each specimen contained at least one section made of each of the four alloys investigated. The specimens were investigated using a JEOL JSM 590 scanning electron microscope with EDS facilities and a backscattered detector. For the deposit specimens, a sample of deposit was removed from the ring, and in addition the ring specimen was cross-sectioned. All specimens were prepared without the use of water as a lubricant.

5.8.2 Potential for Long-term Corrosion and Deposition Impacts

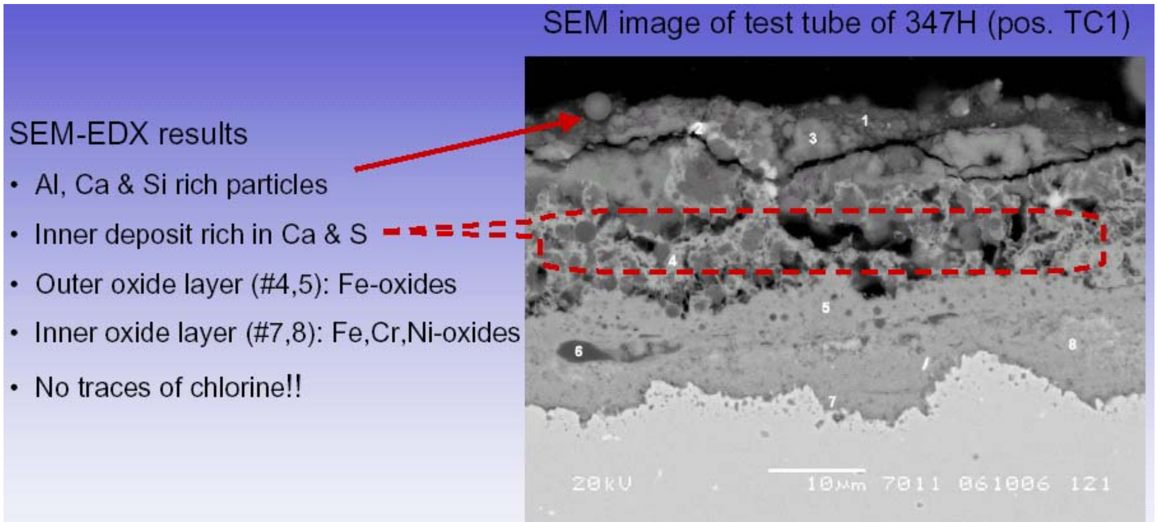
Visual inspections on site, in general showed no visual sign of corrosion or erosion in the inspected areas of the boiler and no significant differences were observed between the inspections before and after cofiring test periods. In all deposit specimens analyzed on the test rings (Exhibit 106), sulfur was enriched in the inner deposits. Sulfur originates mainly from the coal. No chlorine and only minor amounts of potassium were present in the inner deposit of the co-firing specimens. It can be concluded that the risk of chlorine-induced corrosion due to cofiring with up to 5%-weight switchgrass is remote. Furthermore, it was concluded that cofiring switchgrass in the applied amounts does not considerably affect the elemental composition of fly ash.

Exhibit 106 Example Deposit Probe Samples



After exposure, the corrosion test coupons were removed from the boiler and shipped to the laboratory for metal loss measurements and SEM analysis. To estimate the metal loss, pre-exposure and post-exposure measurements were undertaken using a profile projector. The profile projector was set to measure the metal thickness of the test coupons at 8 different positions around the metal circumference. For selected coupons the metal loss was both measured in the steam inlet and outlet end of the coupon. This gives metal losses due to both corrosion on the fire side and oxidation on the steam side. In addition, selected test coupons were mounted in epoxy resin and metallographically prepared for SEM investigation. The specimens were investigated using a JEOL JSM 590 scanning electron microscope with EDS facilities and a backscattered detector. The corrosion coupons were analyzed in the areas around the circumference. These areas were located in the windward side (upstream). The SEM-EDS analyses (Exhibit 107) provided the elemental compositions of both the inner deposits as well as the oxides.

Exhibit 107 Deposition and Corrosion Analysis Example



The report findings for the deposition and long term corrosion testing were:

- The corrosion studies indicated that switchgrass co-firing (up to 5%-weight) had virtually no influence on the corrosion behavior:
  - All together the corrosion investigation indicates that sulphidation and oxidation are the dominating corrosion mechanisms during both 100% coal firing and switchgrass co-firing. The sulfur input with switchgrass is negligible compared to that of the coals.
  - No evidence of chlorine-induced corrosion was observed.
  - Only small amounts of potassium were found in the inner deposits.
  - No distinct difference in the corrosion resistance was observed between the four steel materials tested.

- The deposition investigation indicated that:
  - Neither the deposit chemistry nor the deposition behavior was significantly affected by cofiring of up to 5%-weight switchgrass.
  - The deposition flux to the super/reheaters was unaffected by co-firing.
  - A marginal increase in the concentration of water-soluble potassium of the deposits and fly ash was observed.
  - Generally, the effects of cofiring 5% switchgrass (on a weight basis) were low compared to that of variations in the coal composition.

- Cofiring switchgrass in the applied amounts does not considerably affect the elemental composition of fly ash.

5.9 Other Power Plant Impacts

Other potential impacts of cofiring switchgrass on plant operations were also considered. Detailed boiler efficiency calculations were performed after the Interim Test Burn to compare boiler efficiency during coal-only operation to that during cofiring operations. No significant differences were detected. A series of graphs plotted from the plant's EtaPRO data system for the time period including the Long Term Test Burn is provided at the end of Appendix J. The graphs include plant heat rates before, during, and after the Long Term Test Burn. No apparent significant differences in heat rate occurred during the switchgrass test burn period. Opacity and soda ash feed rates are also plotted for the periods before, during and after the test. Due to observations during the Interim Test Burn that cofiring switchgrass increased opacity, plant operators pre-emptively increased soda ash addition rates by about 0.25 to 0.5 pounds per ton of coal higher than rates that would have been applied if the plant was operating in a coal-only mode. This increased soda ash feed rate is evident by examining the plots at the end of Appendix J. All other potential impacts considered, aside from those mentioned previously in this chapter (coal flows and combustion air flows), seemed not to be significantly effected by switchgrass cofiring, or the impact was less than the impact of varying coal or other conditions at the plant.

6 Economic and Business Issues

Since its outset, the objective of the Chariton Valley Biomass Project (CVBP) has been more than simply to complete a research and development program. The driving objective has been to complete all of the research, demonstration, and development required to lay the groundwork for a viable first-of-a-kind energy crop business in South-Central Iowa. This chapter summarizes the key economic, business, and contract issues associated with the Chariton Valley Biomass Project and key issues associated with commercialization.

6.1 Fuel Supply Contract Development

Developing an equitable fuel supply contract between the utility buyer and the biomass suppliers is a cornerstone to the long term success of the project. Both the interests of the buyer and seller need to be embodied in the contract if the enterprise is to succeed.

6.1.1 Progress in Developing Contract Terms and Conditions

Several biomass fuel supply contracts have been developed and implemented over the course of this project. In November 2003, Alliant Energy and Chariton Valley RC&D Inc. executed a letter contract under which Alliant Energy contributed funds to CVRC&D equivalent to the heating value of the switchgrass burned at OGS during the project's Interim Test Burn. This was a very small contract in terms of dollar value; however, it was important in setting a precedent for payment for biomass as fuel at OGS. In September 2004, IPL and PrairieLands Biomass, LLC executed a Biomass Fuel Supply Agreement for future commercial operations of the project. In addition to standard contract terms and conditions, the agreement established key details for setting a price for switchgrass fuels, provided quality, reporting, and performance requirements, and provided a list of conditions which would have to be satisfied by both parties prior to beginning commercial operations. A complete copy of the Biomass Fuel Supply Agreement is provided in Appendix M.

In February 2006, IPL and CVRC&D executed a biomass processing contract for the Long Term Test Burn. This Test Burn Processing Agreement, provided in Appendix N, was based on the previously executed Biomass Fuel Supply Agreement for commercial operations, and provided compensation from IPL to CVRC&D to help offset a portion of the costs for conducting the test burn. Under that agreement, IPL paid CVRC&D for services provided for processing the switchgrass and the payment amount was equivalent to the heat content of the switchgrass provided plus the market value of the sulfur reductions that accrued from firing switchgrass at OGS. Operation under this test burn contract was viewed by project partners to be a test of the requirements and procedures that would be necessary to fulfill contractual obligations during commercial operations.

These agreements have set the stage for a long-term fuel supply contract that could be the basis for commercial fuel deliveries and processing for OGS.

6.1.2 Switchgrass Valuation at OGS

In addition to typical fuel supply contract terms and conditions, the Biomass Fuel Supply Agreement that was executed in September 2004 contained the following elements: 1) details on valuing switchgrass fuel at OGS; 2) product quality requirements; 3) delivery, monitoring, and reporting requirements; and 4) a list of "conditions precedent" (conditions which must be satisfied or waived on or before December 30, 2007). The methods for switchgrass fuel pricing are summarized below with values based on results from the Long Term Test Burn and market conditions at that time.

The executed Biomass Fuel Supply Agreement provides formal valuation details for the following items:

- Avoided cost of coal (value of the heat content in the switchgrass)
- Sulfur reductions resulting from replacing a portion of coal at OGS with switchgrass
- The Section 45 Federal Production Tax Credit for electricity production from renewable sources

The agreement also recognized the potential for the development and inclusion of additional value streams associated with using switchgrass as fuel at OGS and acknowledges that the parties would share the value of those additional value streams under terms negotiated at the time that the new value stream becomes available. Future potential value streams explicitly mentioned in the contract were: premium power (i.e., "green power"), renewable energy credits, carbon dioxide emissions reductions, mercury emissions reductions, and value generated by becoming a qualified provider of renewable energy for helping fulfill a renewable portfolio standard (RPS) if RPS requirements are ever increased in Alliant Energy's service territories.[38] An additional value stream that has become relevant since the execution of the Biomass Fuel Supply Agreement is the State of Iowa's renewable energy production tax credit for wind and other renewable energy facilities. The current estimated value for each of these streams is also provided based on market conditions at the time of the Long Term Test Burn.

In addition to the potential values mentioned above, both parties have agreed that cofiring switchgrass at OGS may adversely impact some existing operations at OGS and that the contract price paid for switchgrass would be adjusted to compensate for any additional costs of these adverse effects. Potential adverse impacts mentioned in the contract included, but were not limited to, increased boiler fouling, decreased boiler efficiency, and increased soot blowing requirements. The estimated contract adjustments due to these factors were: $0.051 per ton of switchgrass for decreased

[38] Alliant Energy currently meets its requirements for renewable power generation under Iowa's existing RPS and therefore has no current requirement to increase its renewable generation.

boiler efficiency, and $1.409 per ton of switchgrass for increased fouling and soot blowing. The total estimated adjustment for these factors was $1.460 per ton of switchgrass. The parties recognized that these values would be updated based on results from the Long Term Test Burn. Data collection and analysis following the Long Term Test Burn indicates that there was no measurable decrease in boiler efficiency or significant detrimental impacts due to fouling, slagging, and corrosion due to switchgrass; however, there were noticeable requirements to increase soda ash feed rates to control opacity relative to coal-only operations. The increased costs for increased soda ash feed rates have not been quantified, but are expected to be significantly smaller than the $1.46 per ton of switchgrass in the Biomass Fuel Supply Agreement.

6.2 Environmental Credits and Value

Nearly all renewable energy projects depend upon a marketable environmental value or a regulatory requirement to economically compete with conventional resources. The ones that matter most to the Chariton Valley Biomass Project include:

- Tradable environmental credits generated by reducing sulfur and carbon emissions
- Renewable energy credits or certificates for power produced from renewable resources

At this time there is no renewable portfolio standard or mandate for renewable resources that would be applicable to the project. There is an expectation that there may be a renewable portfolio standard at the federal level in the near future.

6.2.1 Sulfur Credits

The following description of the SO_2 allowance trading system is based upon information provided in an EPA factsheet.[39] Allowance trading is the centerpiece of EPA's Acid Rain Program, and allowances are the currency with which compliance with the SO2 emissions requirements is achieved. Through the market-based allowance trading system, utilities regulated under the program, rather than a governing agency, decide the most cost-effective way to use available resources to comply with the acid rain requirements of the Clean Air Act. Utilities can reduce emissions by employing energy conservation measures, increasing reliance on renewable energy, reducing usage, employing pollution control technologies, switching to lower sulfur fuel, or developing other alternate strategies. Units that reduce their emissions below the number of allowances they hold may trade allowances with other units in their system, sell them to other utilities on the open market or through EPA auctions, or bank them to cover emissions in future years. Allowance trading provides incentives for energy conservation and technology innovation that can both lower the cost of compliance and yield pollution prevention benefits.

[39] From the EPA website: http://www.epa.gov/airmarkets/trading/factsheet.html as last updated on Monday, August 25th, 2008.

Allowances were allocated for each year beginning in 1995. Phase I included certain electricity generating units. EPA allocated allowances at an emission rate of 2.5 pounds of SO2/mmBtu (million British thermal units) of heat input, multiplied by the unit's baseline mmBtu (the average fossil fuel consumed from 1985 through 1987). These allowance allocations are listed in Table A of the Clean Air Act and codified in the Allowance System Regulations (Part 73, Table 1). Alternative or additional allowance allocations were made for various units, including affected units in Illinois, Indiana, and Ohio, which were allocated a pro rata share of 200,000 additional allowances each year from 1995 to 1999.

In Phase II, which began in the year 2000, EPA expanded the group of affected sources to include virtually all units over 25 MW in generating capacity, and tightened the allowance allocation. Allowance allocation calculations were made for various types of units, such as coal- and gas-fired units with low and high emissions rates or low fuel consumption. EPA allocated allowances to each unit at an emission rate of 1.2 pounds of SO2/mmBtu of heat input, multiplied by the unit's baseline. Beginning in 2010, the Act places a cap at 8.95 million on the number of allowances issued to units each year. This effectively caps emissions at 8.95 million tons annually and ensures that the mandated emissions reductions are maintained over time.

Allowances may be bought, sold, and traded by any individual, corporation, or governing body, including brokers, municipalities, environmental groups, and private citizens. The primary participants in allowance trading are officials designated and authorized to represent the owners and operators of electric utility plants that emit SO2.

Recent trading activity on the spot market has ranged from $150 to $190 per ton SO2 according to Cantor Fitzgerald.[40] This value is substantially down from the market values at the time of the Long Term Test Burn ($600 per ton of SO_2).

6.2.2 Carbon Credits

During the economic peer review of the project in 2003, Antares suggested engaging the Chicago Climate Exchange (CCX) as a possible purchaser of RECs or as a purchaser of the carbon values associated with the RECs. RECs were not of immediate interest to the exchange at the time because of its focus on a successful pilot carbon trading activity for members. Alliant, once a CCX member, provided inputs into the formation of the Exchange but decided not to be an active member. Iowa Farm Bureau has been active both in REC purchases and in the Carbon Exchange, so an initial dialogue was started with Iowa Farm Bureau. After an initial review of the registration requirements for carbon sequestration values needed from individual landowners, Antares recommended this was a viable pathway to aggregate farm based soil sequestration benefits but that REC sales may be best reserved for a different market

[40] Cantor Fitzgerald market data published on the website http://www.cantorco2e.com for Monday, December 22, 2008

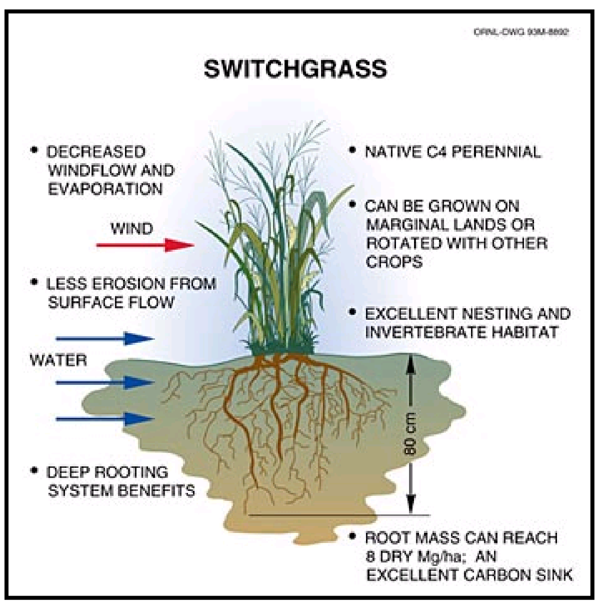
mechanism. As will be discussed below, CCX and Iowa Farm Bureau eventually became important players in this aspect of the switchgrass demonstration program.

Once the Chariton Valley Biomass Project (CVBP) completed the 3-month test burn cofiring switchgrass with coal at Alliant Energy's Ottumwa Generating Station (OGS) in Chillicothe, IA, the partners sought to quantify and sell the carbon credits associated with replacing coal with a renewable biomass fuel (switchgrass) during this test burn. The seller is Chariton Valley Resource Conservation and Development Inc., the managing organization for the project. This project has quantified carbon dioxide (CO2) emissions reductions via three routes:

1) **Replacing a Non-renewable Fossil Fuel (Coal) with Carbon-Neutral Switchgrass Fuel** – Switchgrass is considered to be a carbon-neutral fuel supply. During its growth cycle, switchgrass absorbs CO2 from the atmosphere. When switchgrass is burned at the power plant, an equivalent amount of CO2 is release back into the atmosphere. This creates a closed-loop cycle for absorption and release of CO2. On the other hand, burning coal releases CO2 into the atmosphere from carbon that had been sequestered under ground for millennia.

2) **Immediate CO2 Reductions at the Power Plant due to Reduced Carbon Content in Switchgrass Compared to Coal –** Based on laboratory testing of coal and switchgrass samples throughout the project's test burn periods, switchgrass contains about 17 percent less carbon per Btu of heat content as compared to coal. This results in 17 percent lower CO2 emissions as compared to the CO2 that would have been emitted by obtaining the same amount of heat from burning coal. While these CO2 emissions reductions are real and immediate, the CVBP partners did not count these CO2 emissions reductions as part of the carbon credits they sought to sell.

3) **Switchgrass Sequesters Carbon in the Soil on the Farm –** In addition to the CO2 that was absorbed from the atmosphere and converted to carbon in the portion of the plant that was harvested for fuel, a significant amount of additional carbon dioxide is absorbed during the plant's growth cycle. That carbon is sequestered under ground on the farm in the plant's extensive root system. According to Oak Ridge National Laboratory, as shown in the graphic on the right, the root mass of an established switchgrass stand can

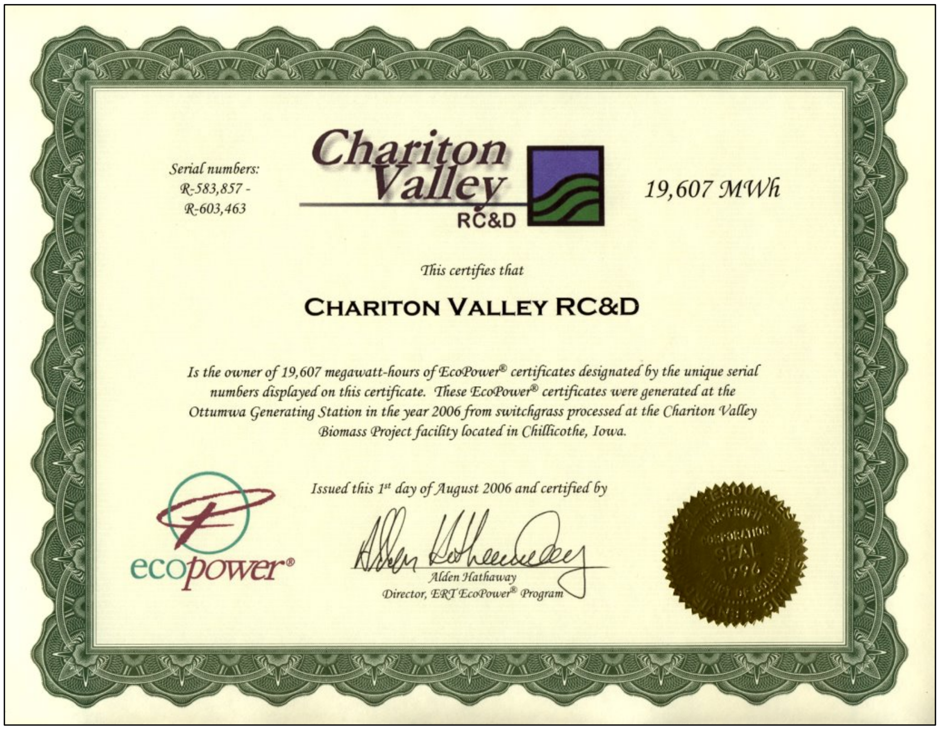


reach 8 dry Mg per hectare (3.56 tons per acre). While this on-farm CO2 sequestration is significant and real, CVBP project partners did not seek to sell carbon credits for on-farm carbon sequestration at this time due to the emerging nature of quantifying and selling these types of carbon benefits, and the complexity involved with issues such as: prior use of the fields, timing of field establishment and harvesting, measured (or assumed) carbon sequestration per acre, lifetime of the switchgrass stand, etc.

The general statistics from the Long Term Test Burn at Ottumwa Generating Station are as follows:

- The project team delivered, processed, and burned 32,188 bales of locally-grown switchgrass. Every bale was weighed throughout the test burn. The total weight of switchgrass burned was about 15,949 tons. This activity occurred on a 24-hour per day basis, 7 days per week, from Feb 17 to May 12, 2006.
- The average moisture content (MC) of the switchgrass throughout the test burn was 13%. Based on laboratory analysis of switchgrass samples taken throughout the test burn, the heating value of the switchgrass was 6,890 Btu/lb (as-received, at 13% MC) and the carbon content was 44.4% by weight (as-received).
- Based on laboratory analysis of coal samples taken throughout the test burn, the heating value of the coal was 8,942 Btu/lb (as-received, at 24.8% MC) and the carbon content was 69.2% by weight (as-received).
- The switchgrass fuel replaced about 12,289 tons of coal purchased from Wyoming with renewable switchgrass that was planted, grown, harvested, stored, delivered, and processed by local Iowa farmers. Coal flow reductions were measured and recorded electronically throughout the test burn using the data monitoring system at the power plant.
- The switchgrass fuel resulted in 19,607,000 kilowatt-hours of electricity generation. This is a world record for electricity generation from switchgrass. The project has obtained an independent third-party certification under Environmental Resource Trust's *EcoPower* program for 19,607 Renewable Energy Credits (RECs) resulting from this renewable electricity generation. Representatives from Environmental Resource Trust performed an independent on-site review of the operations during the test burn as part of their certification and verification process. They toured the entire operation, reviewed all of the data collection and record-keeping procedures, and inspected the equipment and instruments to ensure that the switchgrass tonnage measurements and electricity generation records were reasonable and accurate. An image of the certificate is shown below.

Exhibit 108 Renewable Energy Certificate from Long Term Test Burn



Serial numbers:
R-583,857 -
R-603,463

Chariton Valley RC&D

19,607 MWh

This certifies that

CHARITON VALLEY RC&D

Is the owner of 19,607 megawatt-hours of EcoPower® certificates designated by the unique serial numbers displayed on this certificate. These EcoPower® certificates were generated at the Ottumwa Generating Station in the year 2006 from switchgrass processed at the Chariton Valley Biomass Project facility located in Chillicothe, Iowa.

Issued this 1st day of August 2006 and certified by

ecopower®

Alden Hathaway
Director, ERT EcoPower® Program

Once the Chariton Valley Biomass Project (CVBP) completed its 3-month test burn cofiring biomass with coal at the utility the project sought to quantify and sell the carbon credits associated with replacing coal with a renewable biomass fuel (biomass) during this test burn. The seller was Chariton Valley Resource Conservation and Development Inc., the managing organization for the project. The project's carbon credits were traded on the CCX in a series of transactions that netted an average value of $4.23 per metric ton CO2 emissions avoided by displacing coal at the power plant. The prices ranged from $4 to $7 over the period of time they were traded between November of 2007 and February of 2008. During the process to sell the carbon credits, a third-party verification process was performed to verify the quantity and authenticity of the carbon savings. A requirement for selling the carbon credits on the CCX as to first retire the Renewable Energy Certificates that had been obtained for the test burn period. Sale of both carbon credits and RECs was not allowed by the CCX.

6.2.3 Renewable Energy Credits, Certificates and Power Purchases

6.2.3.1 Federal Production Tax Credits

The renewable energy production tax credit (PTC) supports the development of the renewable energy industry by giving power producers a tax credit for producing renewable energy, assisting the owner to recoup some of the cost of constructing capital-intensive facilities. The main goal of the PTC is to make renewable and alternative forms of energy cost-competitive with traditional, fossil-fuel technologies. According to a November 2007 Lawrence Berkeley National Laboratory report, the Energy Policy Act of 1992 first developed the PTC by providing a 1.5 ¢ / kWh credit for the first 10 years of a renewable facility's operation. The original PTC started only for wind plants in-service between 1994 and mid-1999 with eligible biomass projects being accepted for PTC in 1993. Exhibit 109 details the legislative history of the PTC.

Exhibit 109 Legislative History of the PTC

Legislation	Date Enacted	PTC Eligibility Window (for wind)	PTC Lapse Duration	Effective Duration of PTC Window (considering lapses)
Section 1914, Energy Policy Act of 1992	10/24/1992	1994 to June 1999	None	80 months
Section 507, Ticket to Work and Work Incentives Improvement Act of 1999	12/19/1999	July 1999 to 2001	6 months	24 months
Section 603, Job Creation and Worker Assistance Act	3/9/2002	2002 to 2003	2 months	22 months
Section 313, The Working Families Tax Relief Act	10/4/2004	2004 to 2005	9 months	15 months
Section 1301, Energy Policy Act of 2005	8/8/2005	2006 to 2007	None	24 months
Section 201, Tax Relief and Health Care Act of 2006	12/20/2006	2008	None	12 months
Section 101, Emergency Economic Stabilization Act of 2008	10/3/2008	2009	None	12 months

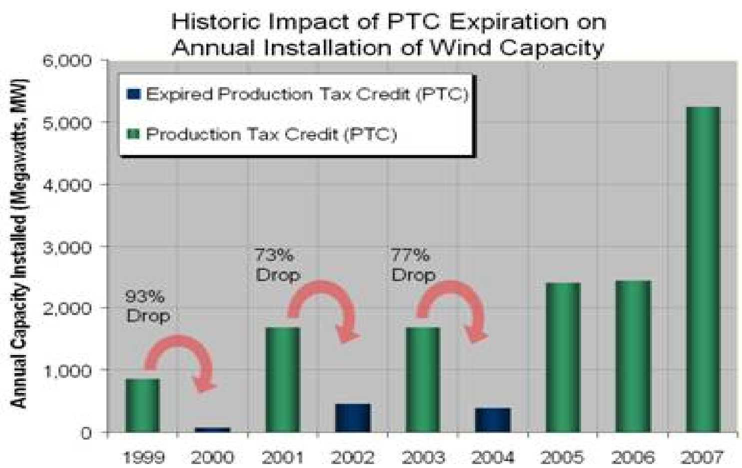
Source: LBNL 2007

Since enactment, the PTC has been extended on six occasions, but only three of these extensions have happened before expiration of the current policy (LBNL, 2007). The

PTC usually receives a one- to two-year extension with a long-term extension being debated throughout the years. The inflation-adjusted value of the PTC stands at 2.1 ¢ / kWh (effective with the 2008 extension) for wind, closed-loop biomass, and geothermal power and half this rate (1 ¢ / kWh) for more traditional open-loop biomass, eligible hydropower, landfill gas, and municipal solid waste (LBNL, 2007). To be considered eligible for the latest extension of the PTC, biomass closed loop cofiring projects must be in service by the end of 2010.

The importance of the PTC is well-illustrated below in Exhibit 110. According to data from the American Wind Energy Association, the three times the PTC has not been renewed has resulted in 73 to 93 percent decreases in annual installed capacity.

Exhibit 110 PTC Extension History



These steep drop-offs in installed capacity illustrate the PTC's importance over the years for driving growth in the renewable energy technology industry. HR 1424, the Emergency Economic Stabilization Act of 2008, continues the PTC, providing valuable incentives useful for stimulating renewable energy project development.

6.2.3.2 Qualified Resources

A summary of the qualified energy resources and facilities is listed below, with particular emphasis on closed- and open-loop biomass.

For the purposes of this report, electricity is defined by the Energy Information Administration (EIA) as the flow of electrical power or charge. It is a secondary energy source which means that we get it from the conversion of other sources of energy, like coal, natural gas, oil, nuclear power and other natural sources, which are called primary sources. The energy sources we use to make electricity can be renewable or non-renewable, but electricity itself is neither renewable nor non-renewable.

Cofiring

The IRS Tax Code includes co-firing biomass with coal. Since payments are only made on a ($/kWh) basis, only electricity produced generates the credit and the Tax Code's language should allow suitable flexibility for qualified biomass facilities to supplement its normal fuel schedule with available biomass feedstock.

The IRS guidance documents also note that "in general," electricity produced from open-loop biomass and co-fired with fuels other than fossil fuels may qualify for the PTC. Guidance documents go on to state that electricity produced from the other fuels used in the co-firing may also separately qualify for the PTC if the other fuels meet the qualified energy resource definition and are placed in service during the required time period.

Cofiring with agricultural livestock waste is also permissible in some instances. For example, an open-loop biomass feedstock other than agricultural livestock waste nutrients may be co-fired with agricultural livestock waste nutrients. However the electricity produced from agricultural livestock waste nutrients may not qualify for the PTC.

Closed-loop Biomass

Closed-loop biomass is simply any organic matter from plants which is planted for the sole purpose of being harvested to produce energy.

Qualified Facilities

According to IRS guidance documents, components of a biomass facility consist of a power plant with all the components necessary to produce electricity. The parts of such facilities include all burners and boilers, any handling and delivery equipment that supplies fuel directly to and is integrated with such burners and boilers, steam headers, turbines, generators, and all other depreciable property necessary to the production of electricity. These facilities are not to include the property used for the collection, processing, or storage of biomass before its use in the production of electricity, transformers or other property used in the transmission of electricity after its production, or ancillary site improvements, such as roads or fencing, which are not necessary to the production of electricity.

According to the IRS Tax Code, all qualifying biomass facilities must be owned by the taxpayer. The biomass feedstock may be co-fired with coal, other biomass, or both, but first the closed-loop modification must demonstrate that it was initiated under the Biomass Power Rural Development program or demonstrate it is part of a pilot project of the Commodity Credit Corporation. A more specific description of how the Tax Code appears to treat likely biomass energy plant configurations is provided below.

New units at existing plants placed in service after enactment of HR 1424 – The Emergency Economic Stabilization Act of 2008 - are eligible for the PTC. New units at existing facilities – both open- and closed-loop - are only eligible up to the amount of increased electricity produced at the facility due to the addition of the new unit.

According to the "Expansion of Biomass Facilities" language in the Emergency Economic Stabilization Act of 2008, expansion for each type of biomass facility "…shall include a new unit placed in service after the date of the enactment of this subparagraph in connection with a facility described in subparagraph (A), but only to the extent of the increased amount of electricity produced at the facility by reason of such new unit."

Open-loop Biomass

The Emergency Economic Stabilization Act of 2008 includes provisions detailing expansion of open- and closed-loop biomass facilities for combined heat and power generation. The IRS Tax Code largely assigns specific types of fuels and fuel sources to the open-loop category. The fuels and sources include:

- Agricultural livestock waste nutrients - livestock manure and litter including wood shavings, straw, rice hulls, and other bedding material for the disposition of manure;

- Solid, non-hazardous cellulosic waste material or any lignin material which is segregated from other waste materials and which is derived from any of the following forest-related resources: mill and harvesting residues, pre-commercial thinnings, slash, and brush;

- Solid waste materials – waste pallets, crates, dunnage, manufacturing and construction wood wastes (other than pressure-treated, chemically-treated, or painted wood wastes), and landscape or right-of-way tree trimmings which does not include municipal solid waste, gas derived from the biodegradation of solid waste, or paper which is commonly recycled; and

- Agriculture sources such as orchard tree crops, vineyard grain, legumes, sugar, and other crop by-products or residues are also considered open-loop.

Term Length of PTC for Biomass

The PTC has varying lengths according to the renewable source of the power plant. Biomass has multiple credit length provisions detailed according to whether the facility is closed or open-loop and the credit length starts with the plant's placed-in-service-date.

According to 2007 IRS tax forms, the PTC credit period is 10 years for a closed-loop biomass facility modified to co-fire with coal, other biomass, or both. The credit period is also 10 years for closed-loop biomass not modified for co-firing purposes. This credit period begins on the date the facility was placed in service, but not earlier than October 22, 2004.

For open-loop biomass, the PTC credit period is 5 years for a facility which uses agricultural livestock waste, beginning on the facility's placed-in-service-date if it is during the period after October 22, 2004, but before August 9, 2005. The credit period expands to 10 years if the placed-in-service-date is after August 8, 2005.

The PTC credit period is 5 years for an open-loop biomass facility using cellulosic waste, beginning on the placed-in-service-date, but no earlier than January 1, 2005.

Credit Value

The credit value for open-loop biomass is 1¢ / kWh and 2.1¢ / kWh for closed-loop biomass. For closed-loop biomass, the credit will equal the amount of fuel determined to be qualified biomass multiplied by the calculated thermal content of the closed-loop biomass used in the facility as a percentage of the thermal content of all fuels used in the facility. The credit value is adjusted for inflation.

Exhibit 111 Major Federal Biomass Incentives

Title	Code	Fuel Type	Incentive	Qualifying Period	Limits[c]
Production Tax Credit – extension[a]	IRC §45	Closed-loop biomass	$0.019/kWhr[b] -2005	In service between 2003 - 2007. 10 year max	phase out above 8¢/kWhr (inflation adjusted)
Production Tax Credit – extension[a]	IRC §45	Closed-loop biomass, co-fired with coal or other biomass	$0.019/kWhr[b] -2005	Anytime before 2008, 10 year max from 10/23/2004 or in-service date	Same as above
Production Tax Credit – extension[a]	IRC §45	Open-loop biomass - existing	$0.009/kWhr[b] (2005)	In service before 1/1/2005, 5 year limit	Credit to operator not owner; phase out above 8¢/kWhr; exclusion of biomass co-fired with fossil fuel
Production Tax Credit – extension[a]	IRC §45	Open-loop biomass - new	$0.009/kWhr[b] (2005)	In service between 8/8/2005-12/31/2007, 10 year limit	Same as above
Renewable Energy Production Incentive (REPI)[d]	42 USCS § 13317	Biomass except for MSW combustion	$0.015/kWhr (1993 $ indexed for inflation)	Renewed appropriations for 2006 - 2026	Available to non-profit electrical co-ops, public utilities, government facilities

Source: CTA-ORNL

6.2.3.3 Green Power

The term Green Power is generally applied to a purchase of renewable energy when the electricity commodity and the environmental benefits are coupled. The following overview of Green Power was published by EPA in its Guide to Green Power Purchases[41].

[41] Guide to Purchasing Green Power, EPA Office of Air (6202J) EPA430-K-04-015 www.epa.gov/greenpower, September 2004.

Renewable electricity products—offered by either the utility or the power marketer that provides the organization's power—can be structured in several different ways. The availability of each of these products varies according to the facility's location and the electricity provider's offerings. Although each product differs slightly, most renewable electricity products fall into one of two types.

Fixed energy quantity block. A block is a quantity of 100 percent renewable electricity, often 100 kilowatt-hours (kWh), offered for a fixed monthly price. The price is often expressed as a price premium above the price of conventional power. Customers usually may sign up for as many blocks as they wish, with the monthly cost of these products based on how many blocks they buy. This type of product is available in some competitive markets but is more often found in regulated utility green-pricing programs.

Percentage of monthly use. Customers may choose renewable electricity to supply a fixed percentage of their monthly electricity use. In practice, this usually results in the purchase of a blend of renewable and conventional power. This is typically priced as a premium on a cents per kWh basis over the standard rate or as a fixed charge per kWh. The monthly cost for these products varies with energy use and the percentage of renewable energy chosen.

6.2.3.4 Renewable Energy Certificates

A REC represents the environmental, social, and other positive attributes of power generated by renewable resources. These attributes may be sold separately from the underlying commodity electricity. For example, RECs represent the reduced emissions of renewable generation compared with those of conventional generation. The actual power that is sold is no longer considered "green" and is treated like any other commodity electricity. In practice, REC transactions can take many forms. Because RECs are sold separately from electricity, they can be purchased from locations anywhere, enabling organizations to choose renewable power even if their local utility or power marketer does not offer a green power product. Although theoretically there are no geographic constraints on buying RECs, accounting systems to record and track the exchange of certificates are not yet available everywhere. In addition, the location of environmental benefits may be important to some purchasers. A variety of REC products are available from local and national sources.

6.3 Calculating the Value for Switchgrass as Fuel for Power Generation

From the above discussion it is evident that the energy replacement value of biomass fuels falls short of the value placed by government and society on the substitution of fossil fuels with renewable fuels. Incorporating the marketable portions of those environmental and societal values into the analysis allows utility companies to decide: What is the premium that can be paid to switch to these renewable fuels without increasing the cost of power to consumers or impairing the profitability of the power generation company?[42]

The table below summarizes the key energy replacement and marketable environmental values that were considered by the project and Alliant in setting a price for renewable switchgrass fuels. Exhibit 112 summarizes the values for which established markets and reliable means for recouping environmental values exist.

Exhibit 112 Value Ranges for Contract Items

Value Item in Contract	Quantity per Ton of Switchgrass	Units	Unit Value ($ per unit) Low	Expected	High	Comments
Values from Executed Commercial Contract						
Switchgrass Heat Content (Btu Value)	13.78	MMBtu	$0.81	$0.83	$0.87	Low is contract value for long term test burn (Feb. 2006). Expected is inflated to Jan. 2007 based on EIA Lignite historical inflation values. High is inflated to Jan. 2007 based on PPI Commodity Fuels & Power inflation factors (per executed contract).
SO2 Emissions Reductions	0.004000301	tons-SO2	$450	$600	$1,624	Low and high values are the 2-yr low and high, respectively, as reported in Air Daily and by Chicago Climate Exchange (CCX). Expected is a conservative estimate based on the most recent 2-yr period.
Section 45 Production Tax Credit	1,253.1	kWhs	$0.0180	$0.0316	$0.0316	Low value is before-tax credit value, discounted by 10%. High value is after-tax value of the credits. Expected value is also after-tax value, consistent with valuation of the Federal PTC in the Commercial Agreement.

These values can be readily captured by the power company in a way that flows to the bottom line. Exhibit 113 lists additional values that are part of an emerging market for environmental attributes that is supporting the introduction of renewable fuels for power generation. It is expected that the markets for renewable energy attributes will continue to grow as the costs of climate change and national security attributed to fossil fuels finds greater political and social acceptance.

[42] There are exceptions to this upper boundary condition determined by marketable attributes. In a regulated utility market the public service commission may deem that the intangible uncompensated benefits will justify an increase in fuel price to the consumer for the benefit of all. On the other end of the spectrum, some consumers may elect voluntarily to pay more for a portion of their power to be renewable (Green Power).

Exhibit 113 Potential Values for Renewable Generation

Value Item in Contract	Quantity per Ton of Switchgrass	Units	Unit Value ($ per unit) Low	Expected	High	Comments
Values from Executed Commercial Contract						
Other Potential Values ***						
Carbon Credits (at OGS)	1.78	tonnes-CO2*	$1.14	$4.00	$4.75	Low value is 2-yr low on U.S. Voluntary Market through Chicago Climate Exchange (CCX). High value corresponds to the 2-yr high on CCX. Expected value is a conservative estimate based on market rates for the previous 9 months.
Carbon Credits (on farm) **	0.46	tonnes-CO2*	$0.00	$4.00	$4.75	
Renewable Energy Credits (RECs) ***	1.2531	RECs (MWhs)	$0.00	$0.00	$1.75	Due to requirement of CCX to retire RECs if carbon credits are sold, no expected value for RECs is assumed. High value is based on high offer prices for RECs that include biomass content in voluntary markets.
Green Power Sales ***	1,253.1	kWhs	$0.0000	$0.0000	$0.0180	The cost premium for green power sold in Alliant Energy's Second Nature program is 2 /kWh. Roughly 1.8 /kWh on average of that premium is passed on to the renewable power projects. Carbon credits would not be allowed to be sold in combination with green power sales.
Iowa R.E. Production Tax Credit	1,253.1	kWhs	$0.0140	$0.0170	$0.0170	Low value is before-tax credit value, discounted by 10%. High value is after-tax value of the credits. Expected value is also after-tax value, consistent with valuation of the Federal PTC in the Commercial Agreement.

When all of these marketable values are rolled into a price that is a benchmark for the potential value of the renewable fuel the full value is 5 to 8 times the energy value alone. This remarkable difference compounds the complexity of arriving at a fair price for switchgrass fuels. Each of these associated values has its own market risk associated with it and it will be unlikely that a contract for the full value will be executed without provisions for adjustment based on the changing market values of the components of the total value. Exhibit 114 summarizes the build up of those marketable values at the time of the Long Term Test Burn.

Exhibit 114 Contract Items Value

Value Item in Contract	Value, $/ton of SWG			Value, $/MMBtu			Value, ¢ per kWh		
	Low	Expected	High	Low	Expected	High	Low	Expected	High
Values from Executed Commercial Contract									
Btu Value	11.17	11.48	12.03	0.810	0.833	0.873	0.891	0.916	0.960
SO2 Emissions Reductions	1.80	2.40	6.50	0.131	0.174	0.471	0.144	0.191	0.518
Section 45 Production Tax Credit	22.56	39.60	39.60	1.636	2.873	2.873	1.800	3.160	3.160
Subtotals	***35.53***	***53.48***	***58.13***	***2.577***	***3.880***	***4.217***	***2.835***	***4.267***	***4.638***
Other Potential Values									
Carbon Credits (at OGS)	2.03	7.12	8.46	0.147	0.517	0.613	0.162	0.569	0.674
Carbon Credits (on farm)	0.00	1.84	2.19	0.000	0.133	0.159	0.000	0.146	0.175
Iowa R.E. Production Tax Credit	17.54	21.30	21.30	1.273	1.545	1.545	1.400	1.700	1.700
Subtotals (Other Values)	***19.57***	***30.26***	***31.95***	***1.420***	***2.195***	***2.317***	***1.562***	***2.415***	***2.549***
GRAND TOTAL	**55.10**	**83.74**	**90.08**	**3.997**	**6.075**	**6.534**	**4.397**	**6.682**	**7.187**

Current Contract Value	53.48 $/ton of SWG	3.880 $/MMBtu	4.267 ¢/kWh
Long Term Test Contract Value	13.88 $/ton of SWG	1.007 $/MMBtu	1.107 ¢/kWh

6.4 Understanding the Costs of Delivering Processed Switchgrass to Alliant / IPL Burner Tips

Compared to computing the values of power generated from electricity, calculating the components of the cost of procuring a processed switchgrass fuel and delivering the fuel to the utility boiler burner tip is relatively straightforward. Although future improvements in yields, harvesting systems and the logistics are likely to occur if the market for these fuels grows, those changes may take considerable time to introduce. The project has already made good progress towards optimizing the production and delivery system using available technology, plant species and establishment methods. The project has worked with Iowa State University to develop an analytical basis for building up the costs based on accepted agricultural production and accounting practices and includes the cost of land, labor, equipment, energy, seed, fertilizer, herbicide and insecticide inputs, and all other costs associated with establishing, harvesting, storing, and delivering switchgrass to a processing facility at OGS.

6.4.1 Building up the costs of switchgrass production and harvesting

Iowa State's analysis of the costs of establishing, producing, storing, and delivering switchgrass to processing facility are included in Appendix NN.[43] Total crop establishment costs were estimated to be $244.59 per acre. Establishment costs are the farmer's capital investment in the crop system and for pricing the product fuel were amortized over the 11 year expected life of the crop at 8% interest or recovery rate. On a per acre basis the capital recovery charge will be $34.26 per year. In addition reseeding costs are ongoing major maintenance costs that are amortized over the life of the crop system as well. Those costs add $6.18 per acre per year to the production

[43] Mike Duffy, Iowa State University Extension, Estimated Costs for Production, Storage and Transportation of Switchgrass, PM 2042 October 2007.

costs. Annual maintenance and harvesting costs are the final cost element of production. The maintenance costs include fertilization and pest management. Harvesting costs are the single largest cost element of production. Total annual production costs are estimated to be $288.46 per acre. At yields of 4 tons per acre per year the expected cost of switchgrass baled in the field would be $82.23.

6.4.2 Transporting and Processing Fuels for Firing

Baled switchgrass is typically transported on open flat bed trailers. The logistical scheme for this project calls for intermediate staging and storage of feedstocks before shipping to limited onsite covered storage at the power plant for processing delivery to the boiler. Iowa State estimated the loading and shipping cost to nearby staging areas would be on average $6.10 per ton. Intermediate covered storage costs including land and building rents and feedstock handling will add on the order of $16.67 per ton. The ability to store large amounts of a seasonal crop to ensure steady fuel flow adds a significant cost to the operation.

The final leg of the journey is transportation to the power plant processing facility. For this project where the supply and staging areas are a good distance from the power plant the average cost is expected to be on the order of $8.65 per ton. This component of the fuel cost brings the total estimated delivered cost to $113.66 per ton.

6.4.3 Fuel Receiving and Processing

The fuel receiving, storage and processing facility was based on similar operations in Europe. This was the first facility of its kind in the U.S. To quantify the operating costs of this facility, the project used the actual operating costs for the final portion of the Long Term Test Burn period as a guide to what commercial operating costs would be. As shown in Exhibit 115, the facility operators gradually improved the efficiency of operations with time over the test burn period. The last 28 days of operation probably best represent the long term normal operating costs at a similar level of production. Land rent and capital cost amortization for the facility construction are not included.

Exhibit 115 Long Term Test Burn Processing and Production

	Test Period Considered			
Parameter Description	**Total Test Burn**	**Last 56 Days**	**Last 42 Days**	**Last 28 Days**
Total Production Costs (SEE NOTE BELOW)	$420,798	$236,924	$179,764	$118,960
Total Tons Processed	15,671	11,071	9,274	6,447
Per Ton Production Costs ($/ton)	$26.74	$21.40	$19.39	$18.45
Overall average hourly processing rate	9.4	8.2	9.2	9.6

NOTE: Production costs consider ALL production related expenses (controller and floor operator labor, all maintenance labor and supplies, rental equipment, diesel fuel, insurance, land lease, and all utilities). This does NOT include any adminstrative expenses (for payroll or project management).

A more detailed summary of the processing facility operational costs during the Long Term Test Burn is provided in Exhibit 116.

Exhibit 116 Operating Costs Associated with Long Term Test Burn

Budget Item Description	*Expenditures thru 9-12-06*	Production Costs last 56 Days	Production Costs last 42 Days	Production Costs last 28 Days
Labor Costs				
Lead Operators	$ 193,912.50	$ 100,650.00	$ 77,400.00	$ 50,100.00
Floor Operators	$ 93,807.90	$ 60,294.77	$ 47,064.58	$ 31,993.58
Administration	$ -	$ -	$ -	$ -
Total Labor	**$ 287,720.40**	**$ 160,944.77**	**$ 124,464.58**	**$ 82,093.58**
Utilities & Other (Insurance, Building Expenses)				
Electricity	$ 83,176.75	$ 33,710.35	$ 23,597.25	$ 15,731.50
Telephone	$ 1,450.58	$ 967.05	$ 725.29	$ 483.53
Water	$ 265.76	$ 62.01	$ 46.51	$ 31.01
Diesel Fuel	$ 4,146.00	$ 2,764.00	$ 2,073.00	$ 1,382.00
Insurance based on Annualized Premium	$ -	$ 7,779.09	$ 5,834.32	$ 3,889.55
Lease Payment	$ -	$ 383.56	$ 287.67	$ 191.78
Total Utilities & Other	**$ 89,039.09**	**$ 45,666.07**	**$ 32,564.03**	**$ 21,709.35**
Equipment Rental Costs				
Loader Lease	$ 23,400.00	$ 15,600.00	$ 11,700.00	$ 7,800.00
Total Equipment Rental	**$ 23,400.00**	**$ 15,600.00**	**$ 11,700.00**	**$ 7,800.00**
Repair & Maintenance				
Misc Supplies	$ 1,859.34	$ 1,239.56	$ 929.67	$ 619.78
Repairs supplies	$ 170.00	$ 10,000.64	$ 7,500.48	$ 5,000.32
Repair Labor	$ 2,559.01	$ 3,473.33	$ 2,605.00	$ 1,736.67
Shipment of coupon material to Denmark	$ 6,349.38	$ -	$ -	$ -
Debaler Screens	$ 1,980.66	$ -	$ -	$ -
Eliminator repair	$ 5,000.00	$ -	$ -	$ -
Power Meter	$ 2,720.07	$ -	$ -	$ -
Total Repair & Maintenance	**$ 20,638.46**	**$ 14,713.53**	**$ 11,035.15**	**$ 7,356.77**
TOTAL ACTUAL EXPENSES	**$ 420,797.95**	**$ 236,924.36**	**$ 179,763.76**	**$ 118,959.70**
Total Expenses per Ton Processed ($/ton)	26.85	21.40	19.38	18.45
Total Tons Processed	15,671	11,071	9,274	6,447
Average Feed Rate (tons per hour)	9.4	8.2	9.2	9.6

The all-included cost of processing is expected to be close to $20/ton when administrative and other miscellaneous charges are added in, bringing total fuel costs up to $133 per ton at the burner tip. However this value should not be directly compared to delivered costs of coal. Storing coal and pulverizing it for firing also carry similar costs and in this report we do not have a direct comparison for those activities since they are not separately accounted for in coal fired plant operations. While calculating this extra step provides the most accurate picture of the true replacement value for purposes of this report the delivered solid fuel costs will serve as a reasonable point of comparison.

6.5 Closing the Gap

Clearly even when all the environmental values are considered there remains a gap between the price that the producers would like to charge for the fuel product delivered to the power plant gate (in this analysis $114 per ton) and the recoverable value including profit that the utility would receive for the electricity commodity ($83 per ton of fuel) based on the value of the energy portion equivalent to coal and including all existing market and tax credit values. We expect significant cost reductions will be achievable through research and hands on experience in fuel production and delivery. A 50% potential increase in the average yield has been reported based on ongoing research that is already being taken up by the private sector and yields in highly managed and irrigated experimental test fields have approached 10 tons per acre per year dry biomass feedstock.[44] A 50% increase in yield does not however translate directly into a 33% reduction in production costs but it would help to close the gap. Larger material volumes on the same acreage will increase annual operating expenses including harvesting.

On the market side the pressures on coal fired generation to improve its environmental profile (e.g. new mercury regulations) are going to continue to increase the value of renewable biomass as an alternative. These advances to close the gap will only come if government support and private investment continues to allow the first facilities to gain the operating experience needed to optimize system logistics and thereby achieve parity in value with conventional fuels (when both energy and environmental values are considered).

[44] Strategic Assessment of Bioenergy Development in the West, Western Governors Association, http://www.westgov.org/wga/initiatives/transfuels/index.html, 9/1/2008.